

November 1999

WIND RIVER WATERSHED PROJECT

Volume I of III

Annual Report 1998



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Wind River Watershed Project

1998 Annual Report

Volume I

November 1999

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**Project Number: 9054
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Executive Summary

This document represents work conducted as part of the Wind River Watershed Restoration Project during its first year of funding through the Bonneville Power Administration (BPA). The project is a comprehensive effort involving public and private entities seeking to restore water quality and fishery resources in the basin through cooperative actions. Project elements include coordination, watershed assessment, restoration, monitoring, and education. Entities involved with implementing project components are the Underwood Conservation District (UCD), USDA Forest Service (USFS), U.S. Geological Survey – Columbia River Research Lab (USGS-CRRL), and WA Department of Fish & Wildlife (WDFW).

The funding cycle of this project did not directly correspond with the fiscal year. Fiscal year 1998 funds did not become available until July 1998. As stated in the FY1998 Statement of Work, the objectives of the project and the entities associated with each objective (lead agency in boldface type) were as follows:

- | | |
|--------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Coordination | <p>Objective 1: Support the Wind River watershed Action Committee (AC). Facilitate the development of a group vision and goals. Task 1.a: Facilitate monthly meetings of the AC. (UCD, WDFW, USFS)</p> <p>Objective 2: Develop a Technical Advisory Committee (TAC) to support AC efforts. Task 2.a: Facilitate meetings of the TAC at least monthly. (UCD, WDFW, USFS)</p> |
| Monitoring | <p>Objective 3: Determine productivity and life history of juvenile steelhead in the Wind River subbasin. Task 3.a: Conduct sampling to derive population estimates for steelhead parr and other salmonids. Surveys will focus on index reaches on the upper Wind River, Panther Creek, and Trout Creek. (USGS-CRRL)</p> <p>Objective 4: Determine smolt production and adult escapement in the Wind River subbasin. Task 4.a: Conduct sampling to derive annual estimates of production of steelhead smolts in the subbasin. (WDFW, USGS-CRRL, USFS) Task 4.b: Conduct sampling to derive annual estimates of adult returns of steelhead to the subbasin. (WDFW, USGS-CRRL, USFS)</p> <p>Objective 5: Evaluate physical habitat conditions in the Wind River subbasin.</p> |

Task 5.a: Evaluate spawning composition on four indexed watersheds including Trout Creek, Panther Creek, Upper Wind and Trapper Creek. **(USFS)**

| | |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Assessment | <p>Objective 6: Assess watershed health using an ecosystem-based diagnostic model that will provide the technical basis to prioritize out-year restoration projects.</p> <p>Task 6.a: Identify goals and objectives for watershed assessment. (USGS-CRRL, WDFW, UCD, USFS)</p> <p>Task 6.b: Perform analysis and diagnosis to formulate restoration strategies with action alternatives. (USGS-CRRL, WDFW, UCD, USFS)</p> |
| Restoration | <p>Objective 7: Reduce road related sediment sources by reducing road densities to less than 2 miles per square mile.</p> <p>Task 7.a: Decommission and restore 4.4 miles of road within the Dry Creek watershed. (USFS)</p> <p>Objective 8: Rehabilitate riparian corridors, flood plains, and channel morphology to reduce maximum water temperatures to less than 61°F, to increase bank stability to greater than 90%, to reduce bankfull width to depth ratios to less than 30, and to provide natural levels of pools and cover for fish.</p> <p>Task 8.a: Place key pieces of large woody debris and implement soil bioengineering techniques along degraded stream reach. (UCD)</p> <p>Task 8.b: Plant and thin riparian vegetation at select sites. (USFS)</p> <p>Objective 9: Maintain and evaluate passage for adult and juvenile steelhead at artificial barriers.</p> <p>Task 9.a: Evaluate the removal or modification of Hemlock Dam. (USFS)</p> |
| Education | <p>Objective 10: Promote watershed stewardship among youth by involving at least 30 students in environmental education programs in local schools.</p> <p>Task 10.a: Develop and support a Streamwalk type program at Stevenson High School. (UCD, USFS)</p> <p>Task 10.b: Support Junior Environmental Trouble Shooters (J.E.T.S.) environmental education program at Wind River Middle school. (UCD, USFS)</p> <p>Objective 11: Raise community awareness of watershed issues by developing and implementing a Wind River Watershed Interpretive Plan.</p> |

Task 11.a: Design signs to inform residents about watershed issues and activities. **(UCD, USFS)**

Task 11.b: Distribute brochures to inform public about watershed issues and activities. **(UCD, USFS)**

Task 11.c: Conduct community volunteer event to involve local residents in watershed activities. **(UCD, USFS)**

Objective 12: Promote watershed stewardship among landowners by providing technical assistance.

Task 12.a: Assist Washington State University Cooperative Extension in hosting technical workshops for landowners. **(UCD)**

Task 12.b: Assist agency personnel and landowners in the development of three stewardship plans. **(UCD)**

Progress towards these objectives is described within nine separate reports included in this three-volume document. The reports, and the objective they address, are: Report A (Coordination), B (Assessment), C (Monitoring), D (Monitoring), E (Monitoring), F-Part I (Restoration), F-Part II (Restoration), G (Education), and H (Restoration).

Report A: Coordination

Wind River Watershed Project

1998 Annual Report

November 1999

Prepared by:

Gardner Johnston

Underwood Conservation District

P.O. Box 96

White Salmon, WA 98672

Introduction

An important characteristic of the Wind River Watershed Project (WRWP) is the high degree of multi-entity collaboration. All stakeholder groups within the basin, including public agencies, citizens and private landowners are integrated into this comprehensive restoration effort. The structure for this coordination was established just prior to the BPA funded effort and has been refined and expanded during FY 1998 funding.

Wind River Watershed Council

In 1997, the U.S. Fish and Wildlife Service provided funding to the Underwood Conservation District (UCD) to establish a pilot watershed project in the basin. A stakeholder group, dubbed the Wind River Action Committee (AC), was responsible for selecting two “demonstration” restoration projects to be implemented on private lands. The AC was also given the responsibility of planning the future direction of watershed restoration in the basin. At the onset of the BPA project, the AC decided to affirm its position and permanence in the basin and adopted the name Wind River Watershed Council (referred to as Council hereafter) to better describe its operation. Current membership is listed in Table 1.

The Council adopted the following mission statement:

“A partnership which encourages the use of land management practices which sustain and improve water quality, fish habitat, and other natural resources, while contributing to long-term economic and community sustainability within the Wind River watershed.”

The following goals were developed by the Council:

- Sustain and restore water quality, water quantity, and watershed function
- Restore and enhance fish and wildlife habitat with a current emphasis on wild steelhead
- Provide local input and knowledge to watershed enhancement activities
- Promote the mission and goals of the Wind River project through community and school education / involvement programs
- Assure that the current condition of the basin and activities within it are adequately monitored and evaluated for results consistent with these goals
- Provide a unified voice to promote the group’s mission and goals and to facilitate the implementation of watershed enhancement activities
- Address the concerns of landowners, land managers, and resource users, while providing a forum for discussion of natural resource issues related to the Wind
- Protect the customs, culture, and economic stability of the Wind River basin
- Ensure coordination and integration of watershed enhancement activities

Eleven Council meetings were held during the period July 1998 – July 1999. One of these meetings was held at the Stabler Cut-Bank project site and a spring picnic was held at the Wind River Training Center. Guest presentations at meetings included: Patrick Connolly (USGS-Columbia River Research Laboratory) – “Status of Wind River Steelhead”, Mark Clark

(Washington Conservation Commission) – CREP program description, Anita Gahimer (Skamania County) – “Wind River Nursery Land Transfer”, Paul Powers (USFS) – “Stabler Cut-Bank Project Presentation”.

Wind River Technical Advisory Committee

A Technical Advisory Committee (TAC) was created to provide technical support to the Council. This group is made up of specialists in fisheries, water quality, forestry, geomorphology, and education. Current membership is listed in Table 1. Six meetings of the TAC were held for the period July 1998 – July 1999. The meetings accomplished interdisciplinary coordination, information sharing, developing a technical project-scoring process, and scoring projects for prioritization.

Project Development Process

The Council and TAC jointly created a project-development process that is detailed in Report B – Watershed Assessment. Three projects were put through this process during the 1998 Statement of Work contract period. Only one project, the “Salmon in the Classroom” proposal by the U.S. Fish and Wildlife Service (USFWS), has received final approval by the Council to be submitted for funding to appropriate sources as available.

The UCD received \$49,500 from non-BPA sources to conduct two habitat restoration projects on the lower Wind River. The funding was federal money that has been channeled through the State of Washington for habitat restoration. The two projects were prioritized by the Council in 1997.

The UCD drafted an Operations/Overview document (UCD 1999) that describes in detail the structure and operations of the watershed project. This should be consulted for additional information.

References

UCD (Underwood Conservation District). 1999. Wind River watershed restoration project - operations / overview. White Salmon, WA.

Table 1. Membership lists of the Wind River Watershed Council and its Technical Advisory Committee.

WIND RIVER WATERSHED COUNCIL

As of July 1999

| | |
|------------------------------|----------------------------------------------|
| Martin Auseth | Southwest Washington Health District |
| Khozrow Bazrafshan | Delano Wind River Mine |
| Joe Birkenfeld | Wind River Logging Company, Landowner |
| Jeff Breckel, Rich Kolb | Lower Columbia Fish Recovery Board |
| Jan Camp | Williams Gas Pipeline - West |
| Lee Carlson | Yakama Indian Nation |
| Anita Gahimer | Port Of Skamania County |
| Daniel Gundersen | Landowner |
| Steve Hansen, Chris Lipton | Longview Fibre |
| Ole Helgersen | Washington State Univ. Cooperative Extension |
| Kwang Ho Baek, Jordan Kim | Carson Hot Springs |
| Howard Houston | Economic Development Council |
| Kevin Kilduff | Central Cascades Alliance |
| Don Lane | Wind River Resorts International Inc. |
| Dave Howard, Tom Loranger | Washington State Department of Ecology |
| Jim Mickel | High Cascade Inc. / WKO |
| Gary Morningstar | Sportfishing, Fish Recovery Board, landowner |
| Chris Neilson | Northwest Service Academy |
| Kevin O'Rourke | Wind River Middle School |
| Gary Owen | Skamania County Public Works Department |
| Rich Rush | Fisherman |
| Al McKee, Harpreet Sandhu | Skamania County |
| Bill Thorsen, Cheri Anderson | USFWS - Carson National Fish Hatchery |
| Bill Weiler | Washington Department of Fish & Wildlife |
| Ken Wieman | USFS - Wind River Ranger District |

Technical Advisory Committee

As of July 1999

| | |
|----------------------------------------|------------------------------------------------|
| Cheri Anderson, Education / outreach | U.S. Fish and Wildlife Service |
| Lee Carlson, Fisheries | Yakama Indian Nation |
| Bengt Coffin, Hydrology | USFS - Wind River Ranger District |
| Pat Connolly, Fisheries | USGS - Columbia River Research Lab |
| Tim Cummings, Fisheries | U.S. Fish and Wildlife Service |
| Mark Engel and Mary McDonald, Forestry | WA Dept. of Natural Resources |
| Ole Helgersen, Forestry | Washington State Univ. Coop. Extension Service |
| Chris Lipton, Forestry | Longview Fibre Corporation |
| Dan Rawding, Fisheries | WA Dept. of Fish and Wildlife |
| Susan Shaw, Geomorphology | WA Dept. of Natural Resources |
| Steve Stampfli, Water Quality | Underwood Conservation District |
| Ken Wieman and Brian Bair, Fisheries | USFS - Wind River Ranger District |

Report B: Watershed Assessment

Wind River Watershed Project

1998 Annual Report

November 1999

Prepared by:

Patrick J. Connolly (USGS-CRRL)

Dan Rawding (WDFW)

Kenneth Wieman (USFS)

Brian Bair (USFS)

and

Gardner Johnston (UCD)

Introduction

Our progress on watershed assessment includes determining goals, objectives, and tasks for the assessment, documenting life history strategies of steelhead in the Wind River watershed, and formulating criteria to help rank restoration needs and proposed projects. Each of these areas of progress is described below under specific headings.

Goals and Objectives of Wind River Watershed Assessment

We developed goals and objectives during a meeting with project personnel, which included all authors of this report. The goals and objectives that we derived are as follows:

Goal: Use a science-based prioritization process to identify effective restoration projects and management alternatives for enhancement of watershed health.

Objective 1. Refine and expand USFS's (1996) Wind River Watershed Analysis.

Task 1a. Incorporate new information, especially that being collected on private lands.

Task 1b. Incorporate data into existing indexes of the watershed analysis for prioritization of sub-basins for restoration.

Objective 2. Diagnose watershed health using steelhead as an indicator species

Task 2a. Identify life history patterns and key environmental attributes for steelhead in the basin

Task 2b. Use an environmental attribute rating system to evaluate steelhead performance over their entire life cycle.

Task 2c. Compare existing and historic conditions using the rating system developed in Task 2b.

Objective 3. Prioritize projects based on ratings, cost effectiveness, and stakeholder objectives (i.e., desired future condition, socioeconomic considerations).

Task 3a. Develop a method for soliciting project proposals from public and private entities.

Task 3b. Develop a method for ranking proposed projects based on results of Objective 2 above.

Task 3c. Develop a method for incorporating socioeconomic considerations into the project ranking process.

Life History Trajectory and Classification of Key Habitat

In partial fulfillment of Task 2a, we collected information that was available on juvenile and adult steelhead populations to assess life history strategies and to identify key habitat. Dan Rawding (WDFW) has drafted a written account of the information, and Pat Connolly (USGS-CRRL), Ken Wieman (USFS), and Brian Bair (USFS) have reviewed it. These reviews need to be incorporated before the document is ready for release. We will be revisiting this effort in fall 1999.

Project Prioritization

In partial fulfillment of Objective 3, the Council and TAC have jointly developed a project development process. The Council and TAC work collectively to solicit projects and to prioritize these activities for funding. Top priority projects are submitted to various funding sources, primarily state and federal agencies that allocate money for anadromous fish habitat restoration, including BPA. To ensure that available funds target the most important projects, proposed projects are put through a basin-wide prioritization process. Public and private entities (including small private landowners) seeking funding to conduct restoration projects in the basin are strongly encouraged to submit proposals to the Council to be put through this prioritization. This ensures the best use of available funds and increases the likelihood of project funding due to support and backing by the Council.

Project development begins with review of proposals by the TAC for technical merit. Proposals then go through review by the Council for socioeconomic and other considerations. Appendix A depicts the relationship between these entities for reviewing projects.

Technical Review of Projects

- Project descriptions are submitted to the Council / staff on a standard form (see Appendix B) and are sent to TAC members prior to the meetings.
- At the meeting, the TAC uses a criteria checklist to assign a numeric score to each project (see Appendix C). There are separate sets of criteria used for restoration and research/monitoring/assessment projects. Education projects have no set criteria and are evaluated on a case-by-case basis.
- After a score is assigned, the TAC votes whether or not a project will be forwarded on to the Council. If a project is not forwarded, it is sent back to the project sponsor with comments, suggestions, and explanations, and can be resubmitted later.

Watershed Council Review of Projects

- Projects are forwarded to the Council with a technical score and any comments by the TAC. Project descriptions are included with the mailing of the Council's meeting agenda.

- At the meeting, the Council reviews each project according to the following criteria and any other special considerations:
 - Cost-sharing available
 - Benefits to landowners
 - Benefit to community
 - Economic development
 - Educational value
 - Community support
 - Available funding
 - Permitting requirements
 - Cost benefit
 - Safety concerns
 - Aesthetics
 - Recreation benefits
 - Regulatory history
- The project is prioritized according to the technical score unless the Council chooses to adjust the project's priority in light of the above considerations. The final prioritization is used to determine which projects are submitted for funding. Because not all projects are appropriate for all funding sources, projects may be passed over for more appropriate, but lower-ranked, projects.
- The Council may determine that the project should not be submitted for funding, in which case the Council sends the project back to the TAC and the sponsor with an explanation. The project can then be resubmitted, with changes, to the TAC, and the process is repeated.

References

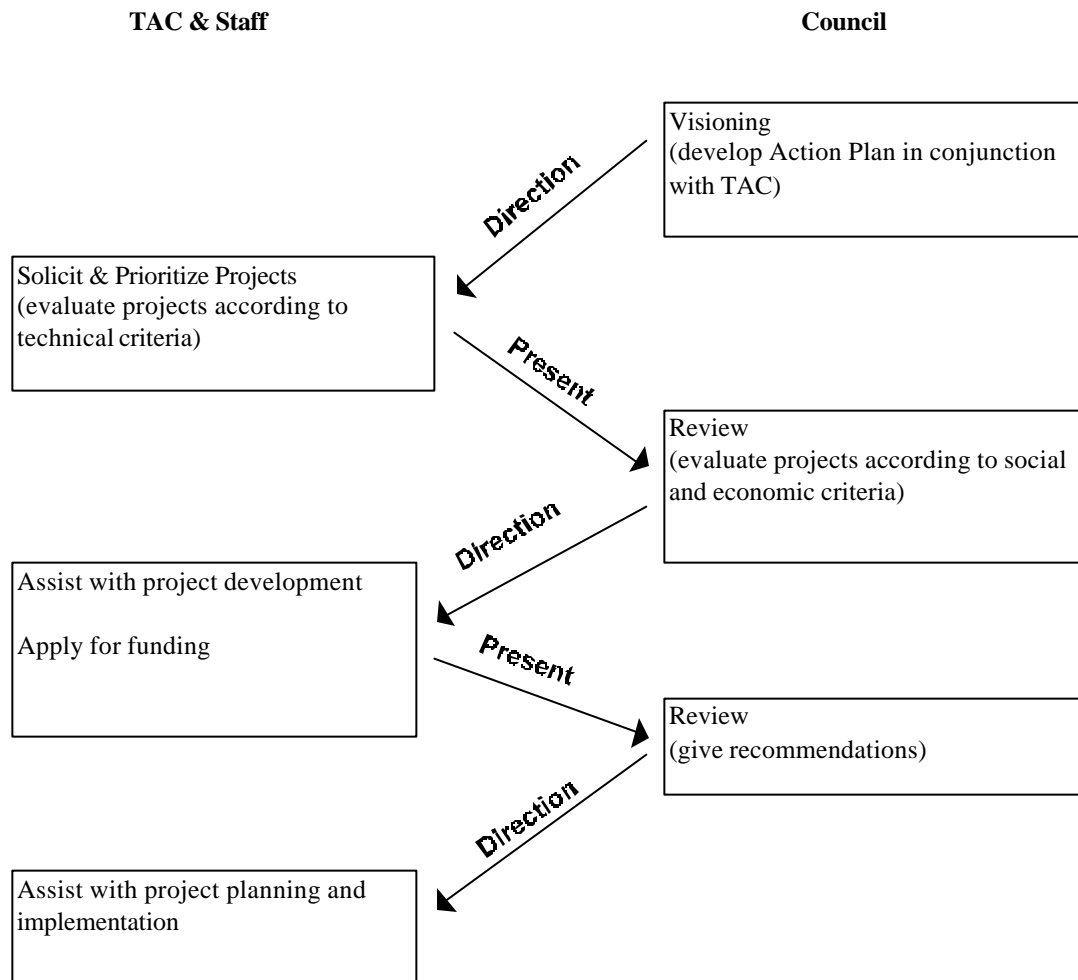
USFS (U.S. Forest Service). 1996. Wind River basin watershed analysis. Wind River Ranger District, Carson, Washington.

Appendix A

Project Development Method for the Wind River Watershed

Watershed Council → Visioning

Watershed Council and Technical Advisory Committee → Development of specific objectives for watershed enhancement - eventual “Watershed Action Plan”



Appendix B

Wind River Watershed Project Proposal Form

1. Project Name

2. Project Type (check all that apply)

- | | |
|-----------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| <input type="checkbox"/> Land Acquisition (fee simple, lease or conservation easements) | <input type="checkbox"/> Plans or Studies (i.e. watershed planning, assessment/inventories/project prioritization) |
| <input type="checkbox"/> Restoration/Enhancement (uplands) | <input type="checkbox"/> Monitoring |
| <input type="checkbox"/> Restoration/Enhancement (wetlands) | <input type="checkbox"/> Barrier Modification |
| <input type="checkbox"/> Restoration/Enhancement (riparian) | <input type="checkbox"/> Barrier Removal |
| <input type="checkbox"/> Restoration/Enhancement (instream) | <input type="checkbox"/> Education/Interpretation |
| <input type="checkbox"/> Administrative Capacity (inadequate staffing/lack of administration funds) | <input type="checkbox"/> Other _____ |

3. Applicant / Organization Information

(For the organization which seeks funding)

Organization Name: _____

Organization Type:

- ☐ City/Town
- ☐ Conservation District
- ☐ County
- ☐ Engineering/ Public Works
- ☐ Native American Tribe
- ☐ Port District
- ☐ Public Utility District
- ☐ School
- ☐ Club
- ☐ Not for profit organization
- ☐ Landowner
- ☐ Other: _____

Organization Address

Address: _____

City/Town County State Zip

Telephone: _____ Fax: _____

Email: _____

4. Project Contact

(Who is the project's lead staff person or worker, and how do we communicate with that person?)

Name: _____

Title: _____

Address: _____

City/Town County State Zip

Telephone: _____ Fax: _____

Email: _____

5. Project Location Information

Site Name or Planning Area: _____

Waterbodies Impacted (include main river body & tributaries): _____

Cities: _____ Counties: _____

Longitude: _____

Latitude: _____

and/or

Section/Township/Range: _____

WRIA Number(s): _____ WRIA

Name(s): _____

6. Landowner Information (if applicable)

Owner Name: _____

Address: _____

City/Town County State Zip

Telephone: _____ Fax: _____

Email: _____

7. Driving Directions to Project Site (if applicable)

(Site and vicinity maps are also required)

8. Summary - Description of Project

The following are IDEAS for constructing the project description. Some of these may not apply or may not be known by the project sponsor. All projects will be evaluated. Contact the UCD or other agency personnel for technical assistance.

Project overview: Briefly give an overview and background of the project, geographic scope, relation to other projects, and scientific basis. State which parameters are being addressed (watershed, fisheries, education) and how this project will affect those parameters. Tie to planning documents. Identify if projects have been specifically listed in an assessment.

Existing condition (if applicable): Describe the existing condition, problems, etc. This may include qualitative or quantitative information and include flow data, stream inventory data, vegetation descriptions, water quality data, etc.

Project objectives: e.g., increase bank stability by 50%, involve 50 kids in water quality monitoring

Specific actions: e.g., plant 1000 conifer seedlings on 3 acres of riparian area, conduct 5 classroom presentations and 3 field trips to stream monitoring site for water quality testing. Describe who will conduct the work (e.g., landowner, contractor, agency, volunteers, school teacher, etc.)

Benefits: To water quality, fish and wildlife habitat, watershed health, landowner, community, education, etc.

Project Maintenance: Describe who, what, when

Permits: List any permits needed and who will obtain them

Monitoring Plan: Describe who, what, when. Tie the monitoring to the objectives.

Work Dates: Indicate your anticipated start and completion dates for this project.

* Please indicate if this project can be completed with less than full funding.

9. Site/vicinity map, design map, photos (if applicable):
attach additional sheets if necessary

10. Project Budget and Cost Share

| Description -include and describe wages, contracts, materials, administration, etc -link to specific actions | Funding Source | | | | |
|-----------------------------------------------------------------------------------------------------------------------|----------------|-----------|---------------------|---------------------|-------|
| | Requested | Landowner | Other (identify) | Other (identify) | Total |
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| | | | | | |
| Project total | | | | | |
| Percent of budget | | | | | |

Appendix C: Project Prioritization Checklist

Watershed Restoration proposals

1. Addresses key and/or limiting attributes.....(10 points)_____
These can be high quality attributes or attributes that limit water quality, fish habitat, watershed processes, or other beneficial natural resources. Sources include the Wind River Limiting Factors Analysis, Wind River Watershed Analysis, professional judgment, or other supportable data.
2. Located in areas of high potential productivity.....(10 points)_____
These are potentially high fish producing areas. Sources include the watershed analysis - “Steelhead Biological Hot Spots” ranking, professional judgment, or other supportable data.
3. Provides multiple watershed benefits.....(10 points)_____
Provides multiple watershed/fish/species benefits, e.g. sediment reduction, riparian vegetation improvement, passage, wildlife, water quality, etc.
4. Compliments other past, present, or expected restoration projects.....(10 points)_____
Comprehensive, ties in with projects that are completed, on going or identified in planning documents.
5. Technical merit.....(10 points)_____
The project is technically sound, i.e. objectives are well defined, measurable, and address problems identified in the proposal; practices are technically sound and treat causes. The monitoring plan is complete and measures progress toward meeting the objectives.
6. Cost.....(10 points)_____
How does cost per unit relate to cost per unit of similar projects. Consider level of cost share.
7. Education and community involvement.....(10 points)_____
Project has a specific educational and /or community involvement component, which identifies target participants and describes how they will be incorporated into the project.

Special considerations-identify (consider sponsor qualifications, experience, and success on previous projects)

Total (70)....._____

Research/Monitoring/Assessment proposals

1. Addresses identified need.....(10 points)_____
2. Scientifically credible design and techniques.....(10 points)_____
3. Cost benefit / cost share.....(10 points)_____
4. Results will have widespread application in the Wind River basin.....(10 points)_____
5. Also provides beneficial effects significant to the habitat.....(10 points)_____
6. Innovative approach/concepts/techniques.....(10 points)_____
7. Environmental education, community involvement, professional information sharing.....(10 points)_____
8. Special considerations-identify

Total (70)....._____

Report C: Physical Habitat Monitoring

Wind River Watershed Project

1998 Annual Report

November 1999

Prepared by:

Kenneth Wieman

**USDA Forest Service
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Wind River Work and Information Center
121 Hemlock Road
Carson, WA 98610**

Report C

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Spawning Gravel Study

Introduction

The amount of fine sediment in gravel where salmonid eggs incubate is an important factor that can affect the survival of egg and alevin (Bjorn 1968; Phillips et al. 1975; Tagart 1976; Cederholm et al. 1982; Tripp and Poulin 1986; Young et al. 1990). Large increase in fine sediment loads into stream channels can create intolerable channel modifications in salmonid spawning areas. Land management or natural changes in stream flow can have an affect on the textural composition and quality of substrate. Hall and Lantz (1996), in their coastal Oregon logging study, found that an increase of five percent in fine sediment smaller than 0.83 mm in diameter in redds decreased survival of emergent coho salmon fry (*Oncorhynchus kisutch*). Other authors have demonstrated that fine sediment particles deposited in the streambed reduce permeability, and this caused higher egg-to-fry mortality (McNeil and Abnell 1964).

In order to access the amount of fine sediment in suspected spawning gravels, biologists often sample the gravels to monitor changes in substrate composition. Washington State has established management indices used in the State of Washington Watershed Analysis fish habitat module (WFPB 1995) in forested watersheds on state and private land. Literature supports the statement that fine sediment can limit fish productivity.

Study Objectives

The objective of this study were to:

- 1) Investigate the use of core sampling as an evaluation and monitoring tool in the cumulative effects assessment of impacts of resource management in the Wind River watershed.
- 2) Establish baseline data on substrate particle size composition (particularly percentage of fine sediment < 0.69 mm {hereafter described as %Fine}) of samples collected in steelhead trout (*Oncorhynchus mykiss*) potential spawning habitat in the Wind River watershed.
- 3) Test the effectiveness and efficiency of McNeil core samplers as a sampling method to detect changes in fine substrate.

Methods

Study Design

The study was designed to compare the composition of fine textured particle spawning substrate sampled in the Wind River subbasin. Nine subwatersheds were selected as representatives of a cross section of forest management regimes base on two general criteria evaluated in the Wind River Watershed Analysis (1996) including: 1) land management activities and 2) slope stability and soil stability. The subwatersheds sampled include Trout Creek, Trapper Creek, Martha Creek, Paradise Creek, Panther Creek, Dry Creek, Middle Wind River, Upper Wind River, and Layout Creek.

Study Segment Selection

Selection of sampling sites was based on known spawning activity determined annual indexed spawning surveys conducted between 1990 – 1998 (Appendix D). Indexed spawning reaches typically are lower alluvial channels with gradient less than 2% and are classified as Rosgen stream channel type C (Rosgen 1994). These indexed reaches are all greater than one mile in length. Four stratified random samples were chosen from quarter-mile segments identified on an air photo (1"=500'). These segments were then field surveyed to identify potential spawning sites. Four segments were then randomly chosen to be surveyed for potential spawning gravel. These site locations were flagged in the field and identified on a low elevation photo.

Sampling Site Selection

All potential steelhead-spawning sites were field identified within the randomly chosen, quarter-mile stream segment. Surface substrate particle size, water depth and velocity were key indicators used to determine suitable spawning sites (Kondolf et al. 1993). The area of each potential spawning site was measured. Four of the potential spawning sites were randomly identified one from each randomly chosen stream reach. Four sediment core samples were taken at each randomly selected site to equal 16 samples per stream

Both Trapper Creek and Paradise Creek were not broken into quarter- mile segments because of their limited C channel lengths. Samples in these two Creeks were taken upstream of human disturbance (Government Mineral Spring houses and Paradise Campground) at the first available potential spawning site found.

Sampling Collection Technique

The McNeil sampler (McNeil 1960) was used to extract streambed core samples. Samples were taken by coring the McNeil sampler into the gravel until the bottom of the collection bowl touched the top of the gravel on the outside of the sampler. Samples material was periodically exhumed from the core cylinder as the sampler was driven into the stream bottom using a twisting motion. All sediment was excavated down to the bottom of the cylinder and pulled up into the collection bowl. A plunger with a one-way valve was then slowly inserted into the cylinder to capture any suspended sediment along with liquids. All material was rinsed into a bucket and securely contained.

A McNeil sampler with a nine-inch long cylinder was used to take samples from Trapper Creek and Trout Creek. We consistently encountered a hardpan layer rock obstructing us from fully driving the sampler to the prescribed depth. Consequently, we switched to using a six-inch McNeil sampler for all subsequent samples. Where necessary, multiple samples were attempted to successfully collect a single segment legitimate sample. We continued to sample in an upstream direction to limit agitation or mixing of substrate (exceptions are noted in Discussion).

Sample rejection protocol

A rejection protocol was applied to the sampling procedure to maintain consistency (exceptions are noted in Discussion). The three main criteria used to reject samples were: 1) improper angle of insertion, 2) incomplete insertion, or 3) extensive disturbance of the substrate. Rejection due to improper angle occurred when the McNeil sampler could not be

inserted perpendicular to the streambed. Rejection due to incomplete insertion occurred when the base of the cylinder could not be driven all the way to the stream bed. Rejection due to extensive disturbance was a subjective call depending on amount of mixing or disruption to the surrounding substrate as a result of sampling complications.

Sample Processing

Samples were allowed to settle in the field for a minimum of 36 hours after which time all samples were decanted of clear water prior to transporting buckets from the field.

The samples were sieved through a twelve-inch diameter, 0.297 mm mesh, USGS-standard sieve. Samples were dried on plastic-lined trays and stacked in a ventilated drying tunnel. Dried samples were passed through a set of sieves; 76.10 mm, 50.00 mm, 25.00 mm, 12.50 mm, 9.51 mm, 6.35 mm, 4.76 mm, 2.36 mm, 1.70 mm, 0.841 mm, 0.425 mm, and 0.297 mm, shaking for 10 minutes with an automated shaker. Course material in the 76.10 mm and 50.00 mm size classes were hand sorted. The material remaining in each sieve was then transferred to a tray for weighing.

Data Analysis and Interpretation

The sixteen samples from each of the nine subwatersheds were sorted into ten particle sizes. Data was converted into percent by weight for each particle size, sample site, and stream. Samples were lumped into three to three size classes as follows: Large, 25.00 mm and larger; Medium, 6.35-24.90 mm; Small, 6.34-1.70 mm; and Fines, 1.69 mm and smaller. Mean weights were calculated for each size class.

Evaluation of %Fine in each subwatershed

The weights of all 16 fine particle samples were summed and a mean weight was calculated. The standard deviation was calculated between all 16 samples.

Evaluation of land management affect on %Fine

McNeil core %Fine particles were compared to two land management activities including roading and timber management. Two sediment delivery models were modified from the hydrology module of the Wind River Watershed Analysis (1996) and compared to %Fine. The road sediment analysis relied on total roaded acres to estimate a total volume (tons/acre/y) of sediment routed to the stream course. This value was then displayed as a percentage of total estimated road sediment yielded in the nine subwatersheds studied. A Pearson correlation coefficient was applied to both water quality parameters.

Management induced sediment from timber harvest was evaluated using a modified Aggregate Recovery Percentage (ARP) model (USFS 1988). The ARP data was taken from Wind River Watershed Analysis (1996). The ARP model premise is that hydrologic recovery is a function of vegetative cover. Full recovery is defined as revegetated land containing conifers eight inches diameter breast height (DBH) in size and having a 70% crown closure. An ARP rating of 90% implies that the watershed has the equivalent of 10% clear-cut. For consistency, we used the clear-cut equivalent (CCE) to demonstrate the percent of a land area impacted by timber management (where $CCE = 100\% - ARP$).

Evaluation of soil stability affect on %Fine

The soil stability model describes mass wasting and potentially unstable soils as a percent of the land area of each subwatershed. Percent unstable land was calculated by summing acres of active and past active land slides, debris flows, and potentially unstable soil identified from air photo interpretation.

Results

Overview of Subwatersheds

Sixteen McNeil core samples were taken from nine subwatersheds totaling 144 samples. The average percent fine particles (<1.69 mm) ranged from 6.98 in Layout Creek to 16.98 in the Upper Wind River (Table 1). The %Fine in the entire Wind River basin averaged 12.36 percent.

Table 1. Percentage of fine substrate particles (< 1.69 mm) measured in nine subwatersheds in the Wind River watershed, Skamania County, Washington. Fine sediment was tested using a McNeil Core sampler in indexed spawning reaches. % *Fine* = percent of sediment less than 1.69 mm., *Std. Dev* = Standard Deviation, and *N* = number of samples.

| Subwatershed Name | % Fine | Std. Dev | N |
|----------------------|--------|-------------|----|
| Dry Creek | 14.19 | 3.32 | 16 |
| Middle Wind River | 14.03 | 3.83 | 16 |
| Panther Creek | 14.29 | 5.58 | 16 |
| Trout Creek | 13.92 | 5.49 | 16 |
| Martha Creek | 12.08 | 3.14 | 16 |
| Upper Wind River | 16.98 | 5.15 | 16 |
| Layout Creek | 6.98 | 3.87 | 16 |
| Trapper Creek | 7.44 | 3.52 | 16 |
| Paradise Creek | 12.96 | 4.14 | 16 |

Comparison of Land Management Activity

Two types of land management activity were compared to %Fine substrate including roaded area and timber harvest (Figure 1). Comparison of roaded area indicated a positive relationship to % Fine and a showed a moderately strong correlation ($r = 0.683$). Timber harvest or clear-cut equivalent area indicates a negative relationship and a weak correlation ($r = -0.307$). Specific land management data were not available for Martha Creek.

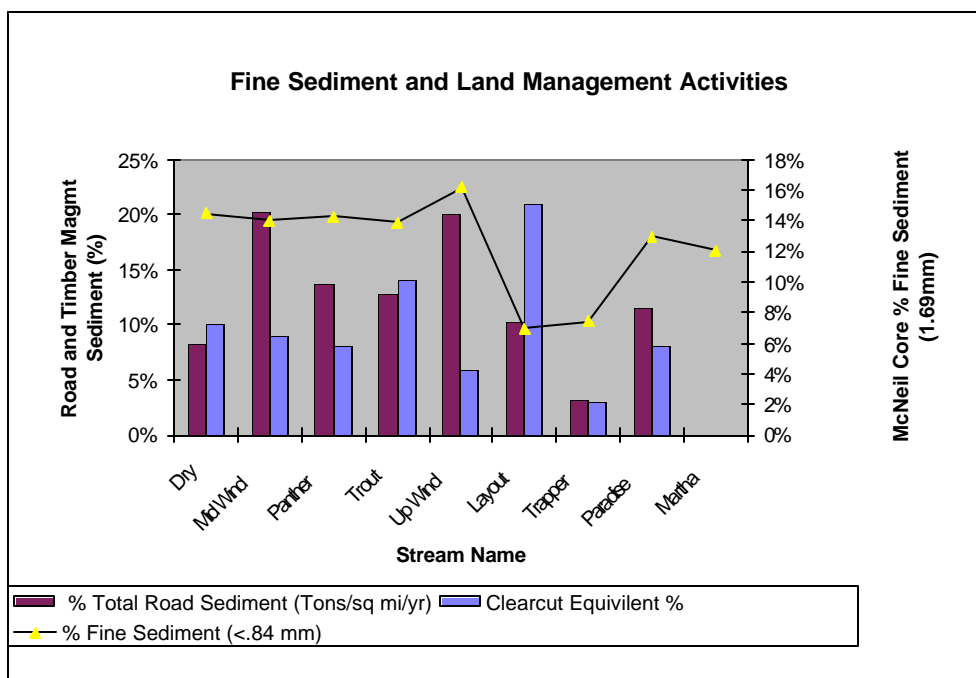


Figure 1. - Relationship between land management activity and fine substrate particle sizes (<1.69 mm) measured in nine subwatersheds in the Wind River watershed, Skamania County, Washington.

Comparison of Soil Stability

Slope failure and unstable soils were other data used to compare %Fine substrate (Figure 2). An evaluation of active or past active landslides, debris or potentially unstable soil indicated a negative relationship to %Fine and a weak correlation ($r = -.358$) to McNeil core samples. Slope stability data specific to Martha Creek subwatershed was not available.

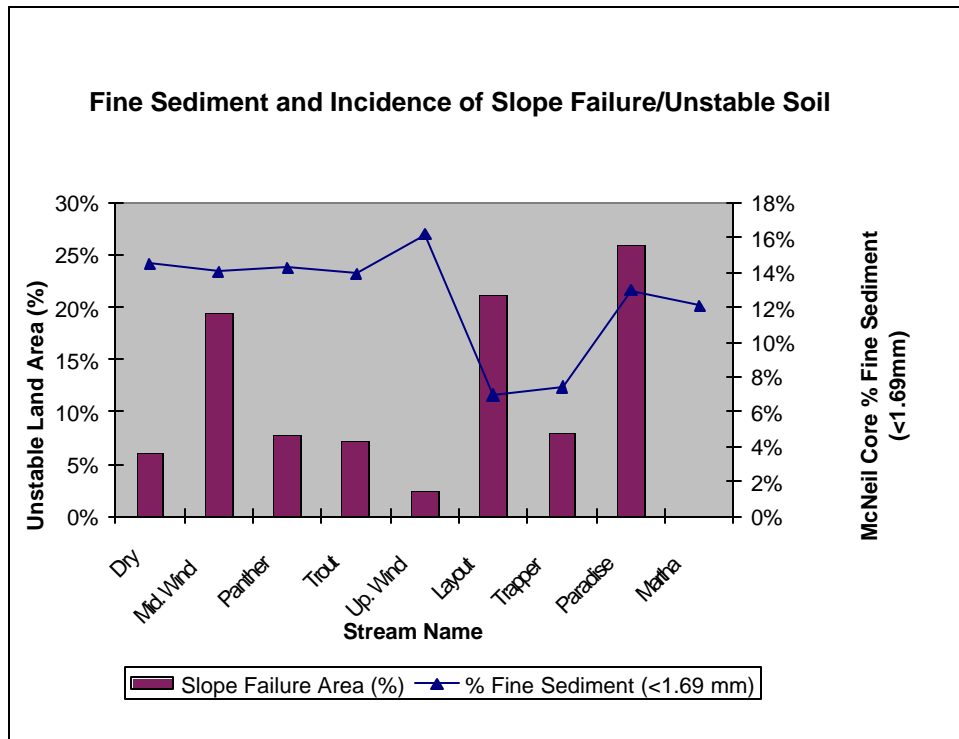


Figure 2. - Relationship between slope failure and soil stability land management activity and fine substrate particle sizes (<1.60 mm) measured in nine subwatersheds in the Wind River watershed, Skamania County, Washington. Slope failure is measured as a percent of land area in a given subwatershed with active or past active landslides, debris flows or potentially unstable soils (Gifford Pinchot National Forest, Soil Resource Inventory 1992).

Comparison of Sample Variability

Comparison of %Fine between the four samples taken at each site developed standard deviations ranging from 0.79 at Trout Creek site #1 to 7.80 at the Upper Wind site #3 (Table 2). The mean standard deviation measured between all sites was 3.22.

Table 2. Standard deviation of percent fines by weight measured at four suitable spawning sites on nine subwatershed in the Wind River watershed, Skamania County, Washington.

| Subwatershed Name | Standard Deviation of percent fine particle substrate (<1.69 mm) | | | |
|-------------------|------------------------------------------------------------------|--------|--------|--------|
| | Site 1 | Site 2 | Site 3 | Site 4 |
| Dry Creek | 3.19 | 1.74 | 2.88 | 4.27 |
| Middle Wind River | 3.48 | 2.49 | 2.68 | 3.23 |
| Panther Creek | 5.41 | 2.49 | 2.68 | 3.23 |
| Trout Creek | 0.79 | 2.05 | 4.79 | 1.04 |
| Martha Creek | 0.75 | 2.51 | 3.37 | 3.91 |
| Upper Wind River | 2.81 | 3.28 | 7.80 | 3.67 |
| Layout Creek | 1.14 | 3.43 | 3.30 | 1.55 |
| Trapper Creek | 2.75 | 3.36 | 3.24 | 2.64 |
| Paradise Creek | 5.07 | 4.61 | 2.88 | 2.18 |

Discussion

Comparison by Percent Fine Sediment

A major focus of this study was to determine the percentage of fines in suitable steelhead spawning habitat in the Wind River watershed. For the purpose of this study, fine sediments were defined as particles < 1.69 mm in diameter (%Fines). The percentage of fine sediments in salmonid spawning has been correlated with the survival to emergence (Cederholm et al. 1982) and to land management activities (Young et al., 1991). Additionally, the percentage of fine sediment <0.85 mm is used as a management indicator of spawning gravel in the 1996 Yakima River Resource Management Plan (YRRMP), and furthermore, it is the threshold for spawning-gravel quality in the Watershed Analysis procedure used by Washington State to evaluate cumulative effects on forest lands (WFPB 1995). All nine streams sampled in the Wind River had a mean %Fine below 17%. This indicates that %Fine is not a high risk to limiting juvenile salmonids survival to emergence (STE). The relatively wide standard deviation between and within streams might indicate that there are local sources of chronic sediment delivery or it could reflect an episodic pulse of sediment moving down through the system following major disturbance such as the 100-year flood of record experience in February 1996.

Fine Sediment and Slope Failure / Potentially Unstable Soils

The slope stability model presented in the Wind River Watershed Analysis (1996) developed a negative relationship that was poorly correlated to %Fine ($r = -0.358$). This model combined three sources of sediment, including active and past active landslides, debris slides, and potentially unstable surface soils. Examining the component parts of this model, however, developed some interesting relationships. As an example, four of the highest %Fine producers, Dry Creek, Panther Creek, Trout Creek, and Upper Wind River, show a strong negative correlation ($r = -0.964$) to erosion land features modeled. A distinction between the deep-seated mass movement and shallow surface- soil erosion may explain the relationship in these four subwatersheds. The combined acres of mass movement (landslides and debris slides) were a relatively small percentage (average = 5.6%) of the total unstable soils modeled (Table C-1). Conversely, potentially unstable soils accounted for a proportionally high percentage (average = 94.4%) of total unstable soils in these four subwatersheds. There is a strong relationship ($r = 0.895$) when comparing the %Fine as a function of the ratio of surface soil erosion to the mass wasting sediment sources. Therefore it may be inferred that %Fine is associated with potentially unstable surface-soil erosion erosional features as opposed to deep-seated erosional features. This notion is supported by Young et al. (1991), who suggest landslides and debris torrents deeply scour stream channels and alter the composition of many sizes of substrate. In his study of juvenile steelhead rearing densities in the Wind River, Connolly et al. (1997) provides supporting biological evidence that landslides may have a limited affect on increased %Fine. Here he observed that Eightmile Creek, a tributary to Panther Creek that was heavily impacted by a substantial 1996 landslide, supported one of the highest densities of age-0 steelhead of streams sampled in the Wind River. The relationship of %Fine with lower bank erosion of floodplain alluvium was not examined in this study. This is, however, apparent in channels that lack lateral lower bank stability such as Middle and Upper Wind, Trout Creek, Layout Creek, and Dry Creek (USFS 1996).

Fine Sediment and Land Management Activities

Two types of land management activities were compared to %Fine: road sediment yield and timber management. There are 31,309 acres currently allocated to timber harvest representing 22 percent of the watershed (USFS 1996). Forest hydrologists use a model of Aggregate Recovery Percent (ARP) to project affects to the hydrologic regime (USFS 1988). A Clear Cut Equivalent (CCE) of 25-30% is considered to be a threshold where there are recognizable changes in water quality and quantity (USFS 1988). Watersheds sampled for %Fine had a relatively wide range of CCE (3–18%). The results of the McNeil core sample did not correlate well with the timber harvest data ($r = -0.038$). The two lowest producers of %Fine, Layout and Trapper creeks, represent the two extreme ends of CCE. Areas of ground disturbance associated with timber harvest are an obvious sediment source. But, due to rapid revegetation of most harvested areas in addition to the streamside buffers and other mitigation applied to harvest units on the National Forest, sediment from these areas (not including the roads used to access harvest units) tends to be relatively short term (USDA 1996). However, the indirect effect of increased risk of peak flows resulting from timber harvest may have a profound influence on lower bank erosion and sediment routing.

Road sediment yield showed a positive relation moderately correlated to %Fine ($r = 0.683$). Middle and Upper Wind River subbasins both have about 20 % of the total road generated sediment and are among the highest in %Fine. Layout Creek, Paradise, and Trapper Creek subbasins are three of the least roaded subbasins and showed a correspondingly low %Fine (10.2%, 11.5%, 3.2%). Dry Creek is conspicuous in that showed a relatively high %Fine but has a considerably lower road sediment yield (8.3%). Factors such as road position on the hill slope, road gradient, road surfaces material, and traffic use are all factors contributing to road sediment yield (Cederholm 1982). These factors may play a role in Dry Creek's relatively high %Fine but were not criteria considered in the road sediment yield model.

McNeil Core Sampling as an Effective and Efficient Method for Detecting %Fine

Several authors have reviewed the McNeil core as a useful means to sample fines with a high degree of accuracy (Young 1990; Schuett-Hames 1996; Grost 1991). Grost (1991) identified shovel methods as being far less time consuming as a result of lighter field equipment.

This initial effort required approximately 160 person days to fully implement (Appendix A). The efficiency of subsequent efforts could be increased by an estimated 20% as a result of increased experience and existing infrastructure. The rate of production was slightly slower than anticipated probably as a result of personnel change and lengthy start up time.

There was a relatively high standard deviation in %Fine within samples taken from the same site. If each spawning site were assumed to be a relatively homogenous with low natural variability in substrate composition, then one would suspect sampling error as the cause. There is insufficient data to support or reject this assumption.

Based on the results of this study the McNeil core sample method can be a reliable indicator of change in %Fine down to 3.22%.

There were several noteworthy sources of error that we experienced in our study. Sampling accuracy may vary because of the following:

- 1) Multiple attempts were necessary to meet the sampling protocol. On an average, four attempts were made for every one sample. Samples from Trapper Creek were particularly difficult to obtain and required as many as ten attempts to retrieve a single sample.
- 2) At a few sites, samples were taken downstream after attempts had been made upstream and may have been contaminated by the new loose sediment from upstream (no specific stream names were noted).
- 3) Fines were lost when the plunger was pushed into the cylinder, as a cloud of sediment came out of the sample hole and fines were also lost during the initial coring of the of the sample (no specific stream names were noted).
- 4) Field decanting samples may have lead to some fines and suspended sediment being lost (no specific stream names were noted).
- 5) A change in McNeil core samplers resulted in coring Trapper Creek and Trout Creek with a nine-inch sampler and the remainder of the streams with a six-inch sampler.

Conclusions

- 1) The McNeil core sampler is a useful means of detecting change in fine particulate substrate.
- 2) The Wind River subwatersheds sampled are not at risk of excessive fine sediment.
- 3) Sources of fine sediment may be generated from surface soil sources including roads and potentially unstable soils.
- 4) The weight and formidable design of the McNeil sampler may limit the efficiency of this method.

Recommendations

- 1) We recommend the continued use of the McNeil sampler to maintain a high degree of accuracy since other studies have shown that it provides the most accurate characterization of overall substrate composition (Young et al. 1991).
- 2) We recommend continued use of the McNeil sampler as a sampling device in effort to maintain consistency with this data set.
- 3) We recommend future sampling crews are provided with additional training in sampling and provided with refined quality control procedures.
- 4) We recommend additional testing of different streams to develop a baseline data set particularly where roading and timber management are ongoing activities.
- 5) We recommend collection of a larger data set encompassing more variety of channel types.
- 6) We recommend evaluating fine sediment as a function of bank stability.
- 7) We recommend additional statistical testing of this data set involving a trained statistician.
- 8) See Appendix B – Technical Notes for further recommendations.

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APPENDIX A – ACCOUNTING REPORT

Table A-1. Personnel accounting report for McNeil core sampling activities conducted on the Wind River, Skamania County, Washington.

| Person Days | Task # | Task Description | Comments |
|---------------------------------------|-----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|
| 20 | 1. 1.1 1.2 1.3 1.4 1.5 1.6 1.7 | Pre-sample preparation <ul style="list-style-type: none"> Acquire equipment (see Appendix B) Develop study design Map and air photo preparation Survey layout Field training Lab set-up Equipment maintenance | <ul style="list-style-type: none"> Acquiring an adequate supply of buckets requires much lead time. |
| 45 | 2. | Field Sample Collection | <ul style="list-style-type: none"> Highly variable daily production. Preferably to work in pairs. |
| 35 | 3. | Sample transport to laboratory | <ul style="list-style-type: none"> Includes decanting samples |
| 45 | 4. 4.1 4.2 4.3 4.4 | Sample Processing <ul style="list-style-type: none"> Dry samples Shake and sieve samples Weigh samples Record data | <ul style="list-style-type: none"> Sampling followed USGS protocol Sampling Conducted in laboratory |
| 15 | 5. 5.1 5.2 5.3 5.4 | Data analysis and report writing <ul style="list-style-type: none"> Literature review GIS map plots Data entry and processing Documentation | |
| <u>Total = 160 person days</u> | | | |

APPENDIX B – TECHNICAL NOTES

Surveying Techniques

- 1) Identify redd sites early in the season (prior to May 15) and label/flag area for future reference. A golf ball dropped in center of redd may serve to detect site during low flows.
- 2) Minimize efforts by conducting field survey possible sample sites prior to the day of sampling. McNeil sampler and transport buckets are cumbersome to move through the woods.
- 3) Extract samples using the six-inch core McNeil sampler. Nine inch core is not necessary to represent steelhead redds and is far more difficult to achieve proper depth.

Sampling Techniques

- 1) Extracting a legitimate sample will require much persistence and patience. Expect to reject approximately three out of every five coring attempts.
- 2) Always work in an upstream direction to minimize disturbance to future sites.
- 3) Reduce hand abrasion and painful pebbles lodged under fingertips by wearing proactive gloves.
- 4) Support bottom of cylinder to prevent the plunger from falling out when lifting loaded sampler.
- 5) Prevent misidentification by affixing labeling to the outside of bucket and securing a second label inside the bucket.
- 6) Decant excess water from field sample to reduce the sample weight and facilitate transport.
- 7) Allow field samples to settle for a minimum of 36 hours prior to decanting excess clear water. Use a filter cloth when decanting water to prevent loss of fines.

Processing samples

- 1) Keep up in preventative maintenance with the shaker. Grease fittings regularly and also allow the shaker to warm up for 10 minutes prior to adding weight.
- 2) Make sure all sieves fit perfectly with bottom pan and green lid on top to prevent them from falling off the shaker while shaking.
- 3) Large substrate (76 mm and 50 mm sieve class) can effectively be sorted by hand after dusting off fines. The remaining sample can be efficiently processed in two sets of five.
- 4) Prevent sieves from sticking together by applying a lubricant on points of contact. Preventative washing will help eliminate sticking as well.

Weighing techniques

- 1) Strictly adhere to proper Mettler scale operation instructions (see manual). Do not move instrument without first locking.
- 2) Have balance professionally calibrated on an annual basis.

Materials and supplies

- (2) 6"McNeil Samplers (lighter and easier to use than the 9")
- (300) 5 -gallon plastic buckets w/ securely fastening lids
- (1) Red bucket lid opener
- (50+) Plastic sheets for drying rocks on
- (1) Shaker machine & Automatic timer
- (2) Complete sieve sets
- (1) Mettler balance and weighing trays

APPENDIX C – MASS WASTING AND POTENTIALLY UNSTABLE SOILS

Table C–1. Mass wasting and potentially unstable soils by Wind River subbasin, Skamania County, Washington (from Wind River Watershed Analysis, USFS 1996).

| Stream Name | Water-shed Size (Acres) | Landslide (Acres) | Percent Landslides by Water-shed | Debris Flows (Acres) | Percent Debris Flow by Water-shed | Potential Unstable Soil (Acres) | Percent Unstable Soil by Water-shed | Total (Acres) | Percent Total by Water-shed | Percent Mass Wasting | Percent Surface Soil Erosion | %Fine Sediment (<1.60 mm) |
|-------------|-------------------------|-------------------|----------------------------------|----------------------|-----------------------------------|---------------------------------|-------------------------------------|---------------|-----------------------------|----------------------|------------------------------|---------------------------|
| Dry | 5754 | 0.00 | 0.00 | 0.00 | 0.00 | 352.73 | 6.13 | 352.73 | 6.13 | 0.0 | 100.0 | 14.5% |
| Mid Wind | 13051 | 590.23 | 4.52 | 0.00 | 0.00 | 1936.02 | 14.83 | 2526.25 | 19.36 | 23.4 | 76.6 | 14.0% |
| Panther | 7184 | 74.50 | 1.04 | 22.71 | 0.32 | 465.14 | 6.47 | 562.35 | 7.83 | 17.3 | 82.7 | 14.3% |
| Trout | 6146 | 22.35 | 0.36 | 0.00 | 0.00 | 425.02 | 6.92 | 447.37 | 7.28 | 5.0 | 95.0 | 13.9% |
| Up Wind | 3509 | 0.00 | 0.00 | 0.00 | 0.00 | 89.14 | 2.54 | 89.14 | 2.54 | 0.0 | 100.0 | 16.2% |
| Layout | 3552 | 43.41 | 1.22 | 5.61 | 0.16 | 700.50 | 19.72 | 749.52 | 21.10 | 6.5 | 93.5 | 7.0% |
| Trapper | 7417 | 154.53 | 2.08 | 9.66 | 0.13 | 430.92 | 5.81 | 595.11 | 8.02 | 27.6 | 72.4 | 7.4% |
| Paradise | 5416 | 83.69 | 1.55 | 0.00 | 0.00 | 1323.66 | 24.44 | 1407.35 | 25.99 | 5.9 | 94.1 | 13.0% |
| Martha | | | | | | | | | | | | 12.1% |
| Total | 52029 | 969 | | 38 | | 5723 | | 6730 | | 86 | | |

APPENDIX D – AVAILABLE SPAWNING GRAVEL SURVEY RESULTS

Table D-1. Estimated available spawning gravel area (ft²) and number of sites in indexed reaches of the Wind River watershed, Skamania County, Washington. (1998 Survey Result). Estimates arrived at by surveying four quarter-mile segments in the index reach.

| Stream Name | River Mile Index | Available Spawning Area (ft ²) / .25mile | Available Spawning Sites avg. # sites/.25 mile |
|----------------|------------------|------------------------------------------------------|------------------------------------------------|
| Middle Wind R. | 11.5-18.1 | 1159 | 1.75 |
| Upper Wind R. | 22.0-25.1 | 7544 | 7.00 |
| Panther Creek | 3.5-6.4 | 782 | 2.75 |
| Layout Creek | 0.0-2.0 | 540 | 5.00 |
| Trout Creek | 6.9-8.9 | 2145 | 4.00 |
| Martha Creek | 1.4-2.4 | 95 | 4.25 |
| Dry Creek | 0.0-2.5 | 359 | 4.75 |

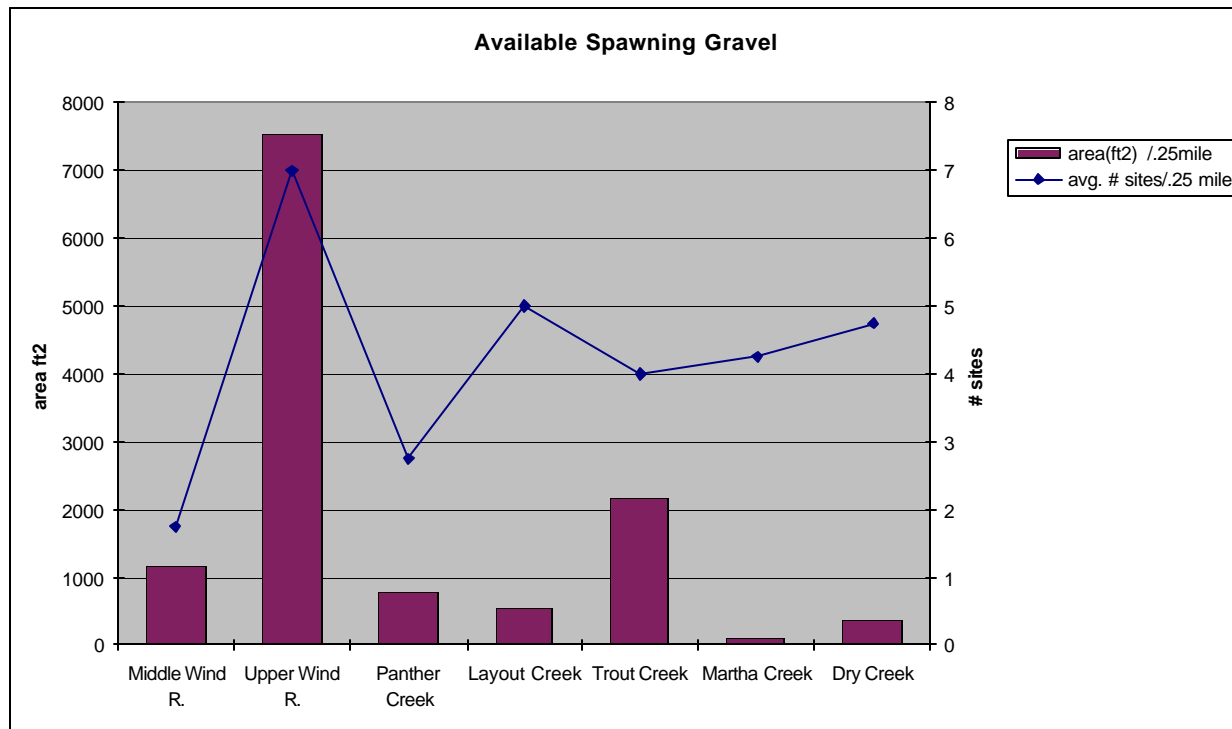


Figure D-1. Estimated available spawning gravel area (ft²) and number of sites in indexed reaches of the Wind River watershed, Skamania County, Washington. (1998 Survey Result). Estimates arrived at by surveying four quarter-mile segments in the index reach.

Stream-Flow Gage Operations

Introduction

Accurate stream flow information is of critical importance in fisheries management and stream restoration activities. The purpose of this task was to maintain and operate a gage station to record stream flows on Trout Creek near Carson, Washington (T4N, R5E, Sec. 24). The gaging station was established in 1994 and operated through 1997 by the USDI Geological Survey (USGS) with funds provided by USDI Fish and Wildlife Service (USFWS). The Wind River Restoration Team (WRRT) is dependent upon accurate stream discharge data for the following:

- 1) Insure compliance with the instream water rights in the Wind River basin.
- 2) Monitor the effectiveness of stream restoration projects in the upper Trout Creek basin.
- 3) Evaluate relationships between stream flow and fish activity including spawning, rearing and migration.
- 4) Acquire data to allow for effective future stream restoration design.

The USGS is the primary repository for stream flow information. The establishment of a gage on the Trout Creek will allow the USGS to:

- 1) Accurately track stream flow conditions in the basin.
- 2) Provide this updated information to resource agencies.

Study Objectives

The objective of this task was to maintain and operate a gage station to record stream flows and develop a rating curve on Trout Creek.

Methods

Monitoring was completed by USGS, who used conventional methods for obtaining water stage data and developing a rating curve as described in Dunne and Leopold (1978). The USGS furnished all materials, supplies, equipment, and labor necessary to access, maintain, and operate the Trout Creek gage house located at the county bridge at river mile 4.3.

Discharge measurements were continuously monitored by obtaining a digital record of stage as a function of time recorded at hourly intervals. The USGS downloaded the record and made discharge measurements by current meter during regularly scheduled field visits. The cross sectional area was charted and velocities were recorded from the county bridge (Forest Road 43).

Results

The water stage data was successfully recorded for water year 1998 (Oct 1998 - Sept 1999) at the Trout Creek gage near Carson. Six field visits were completed and a hydraulic rating curve was developed. The USGS made the data available to users through on-line service and provided the Wind River Restoration Team hard copies of discharge records.

Discussion and Conclusions

Stream discharge data has proven to be very useful. Stream stage has been used as a primary tool for physical and biological monitoring (Report Dxxx). A rudimentary rating curve for Trout Creek was established, but a complete curve for Trout Creek may require several years of data collection (Olson 1999). This period of time is required to observe a range of discharges.

Collection of stream discharge data with methods described above was successful and relatively effective. There are however, several aspects to the site location and project design that are less than ideal for meeting the stated objectives.

Several complications arise due to the location of the gage. Lack of electrical power requires the use of an auxiliary battery source. Reliance on a single power source increases the risk of power failure. Data was lost during the 1996 field season as a result of power failure.

Real-time data transmission is currently unavailable. Gage data is available only following a field visit and manual download of data. This can result in lengthy delays (2-3 months) in obtaining flow data. Consequently, this system is ineffective at providing prompt flow data to support operational management decisions such as smolt trap modification or instream flow adjustments. There are no existing phone lines to transmit signals therefore satellite or cellular phone would be required for remote, real-time transmission.

The existing gage location does not lend itself to effectively monitoring Trout Creek instream flow requirements. Because the existing gage is located upstream of the water withdrawal at Hemlock Lake (RM 2.0), it is not possible to use the gage data to track the instream flows below the diversion. To best monitor the effect of water withdrawals at Hemlock Lake there should be a gage and/or a rating curve developed below the dam and above the dam.

Channel-bottom mobility is another complicating factor at the existing gage location. The gravel/cobble size substrate is relatively to move. Consequently, channel bottom elevation fluctuation may result from substrate aggradation or degradation. This could result in an unreliable rating curve or the need to continuously modify the rating curve.

Recommendations

- 1) Trout Creek gage operation should be continued. This data is critical to develop a long-term analysis, to stream restoration planning and monitoring, and to biological monitoring and instream-flow monitoring.

- 2) Real-time data transfer via satellite or cellular phone transmission should be considered for the future operation of the Trout Creek gage.
- 3) For locating the future Trout Creek gaging station, a site downstream of the dam and water diversion at Hemlock Lake should be considered.
- 4) For locating the future Trout Creek gaging station, a site that is stable over time and suitable for developing a dependable rating curve should be considered.

Acknowledgements

We would like to recognize the significant contributions of USFWS- FRO, specifically Tim Cummings, who provided the technical support, gage infrastructure, and funding to initiate and sustain this project 1995 - 1997. We would also like to thank BPA, specifically John Baugher, for providing funding to maintain and operate the Trout Creek gage in 1998.

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APPENDIX A – TROUT CREEK GAGE FINANCIAL ACCOUNT

Table A-1. Financial account by element/task for Trout Creek gaging station near Carson, Washington (T4 N, R5E, Sec. 24).

Funding in the amount of \$9,480.00, was used by the Geological Survey for activities as follows:

| <u>Element/Task</u> | <u>Amount</u> |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| Salaries (field and office) Includes station inspections, discharge measurements, processing of field data, development of stage-discharge relation, computation of daily discharge (based on 6 visits/year) | \$ 4,580 |
| Travel and Per Diem | \$ 110 |
| Supplies and Equipment Includes instrument rental, stream gaging equipment, office supplies, etc. | \$ 740 |
| Miscellaneous Includes support costs for vehicles, publication, rent, utilities, training, administrative, etc. . | \$ 2,580 |
| Headquarters Technical Service Charge | <u>\$ 1,470</u> |
| Total | \$ 9,480 |
| Challenge Cost Share Distribution | |
| USFS | \$3,580 |
| <u>BPA</u> | <u>\$5,900</u> |
| Total | \$9,480 |

**Report D:
Wind River Steelhead Smolt and Parr Production Monitoring**

Wind River Watershed Project

1998 Annual Report

November 1999

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Abstract

Four rotary screw traps were installed in the Wind River watershed to estimate natural steelhead (*Oncorhynchus mykiss*) smolt and parr production from key reaches. A trap efficiency method from a Petersen estimator was used to develop smolt yield and spring parr production estimates for sub-watersheds. The 1998 smolt yield for the basin and for each key watershed was the highest recorded since monitoring was initiated in 1995. A comparison of 1998 smolt yield and predicted smolt production using two WDFW models indicated that the lower portion of the Wind River is meeting or exceeding expected smolt production and that the Trout Creek watershed is meeting or slightly below modeled projections. However, the upper portion of the Wind River and the Panther Creek watersheds are producing less than 50% of the smolt yield predicted by both models. Differences between observed and predicted smolt production are likely due to habitat degradation, lack of adult wild steelhead escapement, and model imprecision, with habitat degradation a large component of that discrepancy. Therefore, habitat protection in the lower Wind River along with habitat protection and restoration in Panther Creek, Trout Creek, and the upper Wind River are needed to rebuild depressed populations of wild steelhead, currently listed as threatened under the Endangered Species Act.

Introduction

Historically, the Wind River was one of the most productive summer steelhead (*Onchorynchus mykiss*) watersheds in southwest Washington. Bryant (1949) estimated that the pre-1950's wild run size was approximately 3,250 adult steelhead with an escapement of 2,500 fish and a harvest of 750 fish. McMillan (1981), through discussions with anglers, estimated the wild summer steelhead run was between 2,500 and 5,000 fish. The first wild steelhead estimates based on actual fish counts occurred between 1955 and 1965 with the opening of the Shipherd Falls fish ladder. Ladder counts were highly variable due to differences in trapping effort and flows but the maximum wild steelhead count occurred in 1962 with an April through October count of 1,269 fish (NMFS, unpublished data). In the early 1980's the Technical Advisory Committee of the Columbia River Fish Management Plan established an escapement goal of 1,000 wild summer steelhead for the Wind River (TAC 1991). A more refined escapement goal of 1,577 wild summer and winter steelhead was established by Lucas and Nawa (1985) based on the methodology of Gibbons et al. (1985).

The Washington Department of Fish and Wildlife (WDFW) and the United States Forest Service (USFS) have monitored steelhead escapement through redd and snorkel surveys and adult trapping since 1985. Over that period the redd index of adult escapement has declined from a high of 826 wild summer steelhead spawners in 1987 to 94 spawners in 1994 (WDFW 1997). Snorkel surveys show a similar decline with a peak count of 274 wild summer steelhead in 1988 to 44 steelhead in 1997 (WDFW 1997). Due to declining abundance, genetic and ecological risks from hatchery fish, loss of productivity and capacity from degraded habitat, mortality from hydroelectric dams, and the potential of overharvest, the National Marine Fisheries Service (NMFS) proposed that Wind River steelhead be listed under the Endangered Species Act (ESA) (Busby et al. 1996). On March 13, 1998, the wild steelhead in the Wind River were listed as threatened under the ESA.

An interagency work group with members from the USFS, WDFW, U.S. Fish and Wildlife Service (USFWS), and the Yakama Indian Nation (YIN) was formed in 1993 to determine the factors that led to the decline of wild summer steelhead and to develop a rebuilding plan for this population. Since then, the work group has expanded to include the U.S. Geological Survey-Columbia River Research Laboratory (USGS-CRRL), the Underwood Conservation District (UCD), and Washington Trout (WT). The group's goal is to protect, restore, and enhance the productivity of Wind River wild salmonids and their ecosystem. In addition, the group adopted a short-term goal of restoring the wild summer steelhead population size to at least 500 spawners while maintaining the genetic diversity and long-term productivity of these fish. Funding to assist with the recovery of steelhead and steelhead habitat was provided from the Bonneville Power Administration (BPA) beginning in 1998.

Although WDFW adult counts show a negative trend in steelhead abundance, these data are not sufficient to indicate the cause for the decline. Wild Wind River steelhead typically spend two or three years as juveniles in freshwater and two or three years in the ocean, returning in their fifth to seventh year to spawn (WDW et al. 1990). Cooper and Johnson (1992) indicated that the decline in steelhead abundance for Washington steelhead in 1988-89 was due to low ocean productivity. Nehlsen et al. (1991) and the Independent Science Group (ISG 1996) indicated that the declines in Columbia River salmon and steelhead are largely due to habitat losses. Therefore, separate estimates of smolts and adults are needed to determine if changes in freshwater or ocean conditions are responsible for the change in wild steelhead abundance.

The objectives for 1998 were to develop annual estimates of smolt production for the Wind River basin and key production areas within the basin, and to collect juvenile steelhead life history information during the outmigration. This data will be used to help determine factors for decline within key production areas, develop a steelhead and watershed recovery plan based on a science-based assessment, and to determine if watershed restoration activities are effective at recovering steelhead. The 1998 year marked the fourth consecutive spring in which juvenile steelhead outmigration was monitored.

Study Area

The Wind River is located near Carson, Washington. This fifth order stream drains 225 square miles and enters the Columbia River in the Bonneville Pool at River Mile (RM) 155. The watershed provides habitat for summer and winter steelhead, rainbow trout, spring and fall chinook (*Oncorhynchus tshawytscha*), and coho salmon (*Oncorhynchus kisutch*), mountain whitefish (*Prosopium williamsoni*), lamprey (*Lampetra spp*) suckers (*Catostomas spp*), sculpins (*Cottus spp*) stickleback (*Gasterosteus aculeatus*), peamouth (*Mylocheils caurins*), reside shiner (*Richardsonius balteatus*) and leopard dace (*Rhinichthys falcatus*). Prior to the construction of the Shipherd Falls fish ladder at RM 2 in 1956, the only anadromous salmonid accessing the upper watershed were steelhead. The primary purpose of the fishway is to provide passage for spring chinook, which return to Carson National Fish Hatchery at RM 18. The upper portion of the watershed lies within the Gifford Pinchot National Forest. The President's Forest Plan categorizes this basin as a "Tier 1, key watershed" that provides habitat for anadromous salmonids. The USFS manages 77% of the watershed for multi-use benefits. The lower portion the Wind River basin consists of non-federal lands primarily managed for timber harvest.

Methods

Fish Capture

Prior to the start of the steelhead smolt outmigration, four rotary screw traps were installed between late March and early April 1998. The traps were fished until the end of the smolt migration in mid-June. Traps with 5-foot diameter cones were located in the upper Wind River at RM 18, in lower Trout Creek at RM 2, and in lower Panther Creek at RM 2. The trap in the lower Wind River at RM 1 had a larger 8-foot diameter cone. The 1998 Trout Creek and lower Wind River trap sites remained the same as the original sites identified in 1995. However, the Panther Creek trap was moved upstream in 1998 to improve trap efficiency. The upper Wind River site was new in 1998 (Figure 1).

Trap locations were chosen based on the objectives listed above. The upper Wind River and Trout Creek sites are located on USFS property just downstream of proposed or ongoing habitat restoration projects. These sites were chosen to determine if habitat restoration projects increase smolt production. The Trout Creek, Panther Creek, and Lower Wind River sites are located near the lowest portions of these basins to determine smolt yield by key watershed. Site selection was based on access, suitable anchor sites, and stream conditions that produce acceptable trap efficiencies. Two of the sites were located on public land and the remaining two sites were on private land. Trees, large boulders, and abandoned bridge pilings were used to anchor the traps (Figure 2). The traps were fished near the head of a pool, just below a narrow

section of fast turbulent flowing water when available. Traps were positioned so that stream flow entered in a straight line. We generally tried to fish in water velocities greater than 1.5 meter/second producing cone revolutions of >8 rpm on the 5 ft. traps and >5 rpm on the 8 ft. traps. The 1995-97 Panther Creek site had a sharp change in direction that resulted in low trap efficiencies and this trap was moved upstream approximately 100 yards upstream in prior to installation in 1998. Due to extreme low flows in May 1998, the lower Wind River trap was not meeting target trap efficiencies and was moved 100 yards upstream on May 16, where trap efficiencies improved.

All traps were fished 24 hours/day throughout the smolt outmigration period. The lower Wind River trap was not fished for four days following the release of more than two million spring chinook from Carson National Fish Hatchery. A total of 36 hours of fishing time was lost on Trout Creek in late March due to a log in the trap and high flow. In Panther Creek, a total of 24 hours was lost due to debris in the trap. Traps were checked daily in the morning; fish were removed from the live well and placed into aerated coolers. Steelhead juveniles were sorted by life history stage. Wild steelhead were classified as parr, pre-smolt, or smolt. The criteria for parr included well-developed parr marks and heavy spotting across the dorsal surface. Pre-smolts were those fish that had faint parr marks, less prominent dorsal spotting, silvery appearance, and no dark caudal fin margin. Smolts consisted of those steelhead with deciduous scales, silver appearance, and a dark band on the outer margin of the caudal fin. Since smoltification is a process that steelhead undergo along their downstream migration and these Wind River steelhead are more than 150 miles from the ocean, we felt it necessary to classify fish as pre-smolts. For smolt production estimates, smolts and presmolts were pooled. In all cases, captured juveniles were anesthetized with MS-222 (~ 40 mg/l) before handling, sampled as quickly as possible and were allowed to recover fully before being released into the river. Fork lengths (mm) were obtained on all juvenile steelhead and scale samples were systematically collected from a total of 158 fish. Others fish species were identified and enumerated.

Water temperatures were recorded at all trap sites. Stream discharge was obtained from USGS stream gauge stations on the Wind River (RM 2) and Trout Creek (RM 6). Discharges on Panther Creek and the upper Wind River were estimated by a regression analysis of historic discharges for Panther Creek and the upper Wind River compared to historic discharges of the lower Wind River over the same period of time. Strong correlations were found in each case (Table 1).

Table 1. Regression analysis of historic USGS discharge data from gaging stations in the Wind River basin, during the spring months (March - May).

| | UpperWind River (1954-1967) | Panther Creek (1944-1952) |
|----------------------------------|-----------------------------|---------------------------|
| Constant (Y intercept, b) | 111.483 | -12.269 |
| R Squared | 0.927 | 0.883 |
| No. Of Observations | 2045 | 837 |
| X Coefficients (slope, m) | 0.425 | 0.136 |

Juvenile Production Estimates

The number of juvenile outmigrants was estimated by using a trap efficiency method of releasing marked fish upstream of the trap (Thedinga et al. 1994). Captured juvenile steelhead were marked with a Panjet inoculator (Hart and Pitcher 1969). Our marking schedule rotated every week and used different fin combinations to distinguish between traps. This allowed us to identify fish based on trap site and marking period. Trap efficiency is estimated using a modification (Chapman 1951) to the Petersen estimate from the equation $e = (R+1)/(M+1)$, where e is the estimated trap efficiency, M is the number of marked fish released upstream of the trap, and R is the number of marked fish recaptured. The number of migrants at each trap was determined from the equation: $N = U/e$, where N is the estimated number of outmigrants, U is the total unmarked catch, and e is the trap efficiency. The variance for each N was determined by a bootstrapping method (Efron and Tibshirani 1986) with 1,000 iterations from a Fortran program (Murphy et al. 1996). Confidence limits were calculated from the equation: $95\% \text{ CL} = 1.96 * \sqrt{V}$, where V is the variance determined from bootstrapping.

When trap efficiencies are low, the population studied is small, and/or during the early or late portion of the migration, the recapture of marked fish is low. When recaptures during a marking period are expected to be less than five, the addition or deletion of even one fish can make significant change in the estimates of trap efficiency and ultimately population size. Bailey (1951) demonstrated this relatively high bias at low sample sizes and Schwarz and Taylor (1998) indicated there should be at least five recaptured fish per strata. Therefore, mark weeks are pooled to obtain a minimum sample size of five recaptures in every trapping interval. After this preliminary pooling, a series of Chi Square tests were performed to determine if there was a statistical difference between mark groups. If no difference was noted between adjacent mark periods, groups were further pooled to increase sample size and maximize statistical confidence in population estimates. When the significant differences between adjacent mark periods were noted, then samples taken in that period could not be pooled and trap efficiency estimates, population estimates, and variances were individually calculated for the mark period.

At the lower Wind River trap we had marks available from that trap and the three upriver traps. First, we performed a Chi Square test to detect seasonal differences between traps. If there were no significant differences then marks from all traps would be pooled. Next, weekly mark groups from all traps were pooled to ensure the number of recaptures was greater than or equal to five fish. A further Chi Square test on mark groups was conducted. If there was no difference between adjacent mark periods, groups were pooled to tighten the confidence limits. When the differences were significant, trap efficiency estimates, population estimates, and variances were calculated for the mark period by trap.

Murphy et al. (1996) listed the standard assumptions of the Petersen method (Seber 1982) that apply in trap-efficiency experiments: (1) the population is closed; (2) all fish have the same probability of capture in the first sample; (3) marking does not affect catchability; (4) the second sample is either a simple random sample, or if the second sample is systematic, marked and unmarked fish mix randomly; (5) fish do not lose their marks; and (6) all recaptured marks are recognized. During the smolt trapping season, we took steps to reduce the possibility that these assumptions were violated. When possible we conducted experiments to determine the bias caused by violations of these assumptions and develop correction factors.

Results

Migration Characteristics

Since trap catches were zero for the first few days the traps were operated, it was assumed that smolt migration was zero prior to the period of trap installation. Smolt migration began in late March in the upper watershed and smolts continued through mid-June. Upper Wind River and Panther Creek smolt outmigrations peaked in late April, approximately seven to ten days earlier than Trout Creek and the Lower Wind River. Figure 3 displays the date at which 25%, 50%, and 75% of the smolts passed each trap. It appears that smolt outmigration surged when water temperatures increased to 46 to 48 degrees Fahrenheit (Figure 4).

Steelhead smolt lengths ranged from 122 – 254 mm. However, most smolts were between 150 –185 mm. The mean smolt lengths from Trout Creek, Panther Creek, and upper Wind River were 166, 165, and 164, respectively. The mean smolt length in the lower Wind River was larger at 175 mm (Table 2). The length frequency distribution by key production area is shown in Figure 5. The 1 mm discrepancies between maximum length for new and recaptured smolts is due to measurement or rounding error.

A total of 158 scale samples were collected from wild steelhead smolts. Due to low sample sizes in 1998, we were unable to generate a smolt length frequency by age class. Smolt age frequencies by trap are shown in Figure 6. The lower Wind River and Trout Creek produced mainly two-year old smolts, with Panther Creek and the upper Wind River producing mostly three-year old smolts. This age structure is consistent with previous years' data.

Table 2. Summary of steelhead smolt length data by trap site in the Wind River basin, Spring 1998.

| Site | New Smolts (mean) | New Smolts Standard Deviation (S.D.) | New Smolts Range | Recaptured Smolts (mean) | Recap Smolts S.D. | Recaptured Smolts Range |
|------------|----------------------|--------------------------------------------|---------------------|--------------------------------|-------------------------|----------------------------|
| Trout Ck | 166 | 13.99 | 122-204 | 165 | 12.36 | 136-205 |
| Panther Ck | 165 | 15.72 | 128-216 | 157 | 14.82 | 133-195 |
| U. Wind | 164 | 16.49 | 125-247 | 164 | 16.70 | 125-248 |
| L. Wind | 175 | 16.98 | 129-254 | 169 | 13.54 | 125-205 |

The 1998 spring parr migration exhibited a bimodal distribution. The first peak occurred in late April/early May when water temperatures reached the upper forties and then again in early June as flows decreased (Figure 7). Parr lengths ranged from 60 to 270 mm. Since the maximum parr length exceeded the maximum smolt length, it is likely the largest parr are adult resident rainbow trout. Mean parr length ranged from 86mm on Panther Creek to 114 mm in Trout Creek (Table 3). Although, no scales were taken from these fish, it is likely they were age 1 to 3.

Table 3. Summary of steelhead parr length data by trap site in the Wind River basin, Spring 1998.

| Trap Site | Mean Fork Length (mm) | Standard Deviation | Range (mm) |
|---------------|--------------------------|--------------------|---------------|
| Trout Creek | 114 | 27.37 | 76-228 |
| Panther Creek | 86 | 18.96 | 60-270 |
| U. Wind | 97 | 16.18 | 65-210 |
| L. Wind | 109 | 18.34 | 78-167 |

Smolt and Parr Yield

A total of 3,238 wild steelhead smolts were trapped in 1998. We marked 3,174 smolts with alcian blue dye for trap efficiency tests and of these 3,076 fish were cheek tagged with blank wire. Trap efficiencies varied little during the 1998 outmigration. After pooling mark group estimates to obtain 5 or more recaptures, a Chi-Square test indicated that seasonal differences existed at all traps except for Trout Creek. Therefore, we developed a seasonal trap efficiency for Trout Creek and early and late period trap efficiencies for the remaining three sites. Estimated smolt yields with 95% confidence limits by trap are listed in the Table 4.

Table 4. Summary of mark and recapture data for marked groups of Wind River wild steelhead smolts, 1998.

| Trap Site | Sample Period | Smolts Captured | Smolts Marked | Smolts Recaptured | Trap Efficiency | Population Estimate | +/- 95% CL |
|-------------|---------------|-----------------|---------------|-------------------|-----------------|---------------------|-------------|
| L. Wind R. | 4/10-5/9 | 483 | 1629 | 61 | 3.8% | 12,698 | |
| | 5/10-6/12 | 917 | 1532 | 120 | 7.9% | 11,618 | |
| | | | | | | 24316 | 4111 |
| U Wind R | 4/2-5/2 | 395 | 378 | 84 | 22 % | 1766 | |
| | 5/3-6/12 | 313 | 312 | 119 | 38% | 814 | |
| | | | | | | 2580 | 386 |
| Panther Cr. | 3/30-4/25 | 120 | 120 | 37 | 31.4% | 382 | |
| | 4/26-6/8 | 105 | 105 | 10 | 10.3% | 1012 | |
| | | | | | | 1394 | 614 |
| Trout Cr. | 3/20-6/12 | 905 | 903 | 202 | 22% | 4030 | 554 |

Parr production estimates are available only during the spring outmigration, even though parr may migrate at other times of the year. In 1998, we estimated that 6,693, 6,162, and 1,873 parr migrated past the Panther Creek, upper Wind River, and Trout Creek, respectively. Trap efficiency for parr was not tested at the lower Wind River site. However, trap efficiencies for parr and smolts were similar at the other three sites. If we assume the lower Wind River smolt

trap efficiency for parr and smolts was the same, then the lower Wind River parr production estimate is 1,164. Parr outmigrants accounted for 5% of the total spring migrants passing the lower Wind River trap and they accounted for 83% at Panther Creek, 70% in the upper Wind River, and 32% in Trout Creek.

Discussion

Data Accuracy and Precision

The need for accurate and precise population estimates has been well documented by fisheries managers (Walters and Ludwig 1981, Knudsen 1997). Land management agencies and organizations that fund habitat restoration programs are equally concerned with the development of accurate population estimates to assess the effectiveness of protecting and restoring habitat. Rawding (1997) proposed that the smolt-monitoring program on the Wind River should strive to attain 95% confidence limits that are within 20% of the point estimate of the population. The approximate equivalent statistical expression is that the coefficient of variation should be less than 10% calculated from the equation: $CV = SD/N$, where CV is the coefficient of variation, SD is the standard deviation, and N is the population estimate. To improve the coefficient of variation more fish must be caught either through improved trap efficiency or an increase in population size. At the lower Wind River, upper Wind River, and Trout Creek coefficients of variation of less than 10% were achieved in 1998. In Panther Creek the coefficient of variation was 22%, a substantial improvement from the 50% achieved in 1997 but well above our goal of 10%. Due to the low smolt abundance in Panther Creek it will be difficult to achieve a coefficient of variation of less than 20%. In 1998, the following contributed to more fish being caught: 1) trap moves in the lower Wind River and Panther Creek doubled trap efficiency at each site; 2) the addition of the upper Wind River trap allowed us to mark more fish for trap efficiency tests in the lower Wind River; and 3) low and stable flows during the entire outmigration increased the trap efficiency at all sites. The coefficient of variation for the lower Wind River trap has decreased from 30% in 1995 to 9% in 1998. Similar improvements have been observed at all sites and these results are shown in Table 5.

Table 5. Precision of smolt yield estimates in the Wind River, 1995 -1998.

| Trap Site | 1998 Population Estimate | 1998 +/-95% Confidence Limit | 1998 Coefficient of Variation | 1997 Coefficient of Variation | 1996 Coefficient of Variation | 1995 Coefficient of Variation |
|------------|--------------------------------|------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
| L Wind R. | 24,316 | 4,111 | 9% | 18% | 18% | 30% |
| Trout Cr | 4,030 | 554 | 7% | 15% | 19% | 21% |
| Panther Cr | 1,394 | 614 | 22% | ~50% | ~50% | ~50% |
| U Wind R. | 2,580 | 386 | 8% | Not Available | Not Available | Not Available |

Trap Efficiency Bias

The Petersen estimator can provide accurate and precise population estimates if the following conditions are met: (1) the population is closed; (2) no mark loss; (3) all marked fish are properly recognized; (4) marking has no effect on catchability; and (5) all fish have the same probability of being tagged in the first sample or all fish have the same probability of being captured in the second sample.

(1) Closed Population - Closure usually implies that no animals enter or leave between the two sample periods. However, as long as the mortality rate is the same for marked and unmarked animals, the Petersen estimate is still valid (Arnason et al. 1996). Trap efficiency studies are designed to minimize mortality so the assumption of a closed population is usually met. We incorporated procedures to minimize mortality from sampling and handling stress, released fish close to the trap to minimize natural mortality between the release site and the trap, and evaluated the short-term survival of marked fish. Prior to sampling juveniles were anesthetized with MS-222 (~ 40 mg/l). Fish were sampled as quickly as possible and were allowed to recover fully before being released into the river. These procedures helped reduce stress and decrease delayed mortality. The release sites for marked fish are located approximately 1 mile above the trap to minimize natural mortality but still allow unmarked and marked fish to mix randomly. Predation on juvenile steelhead in the Wind River is assumed to be low due to the lack of piscivorous fishes above the traps, and low abundance of natural predators such as river otter (*Lutra canadensis*), mink (*Mustela vison*), and common mergansers (*Mergus merganser*). The high stream gradient (~2%) and boulder substrate combine to create substantial cover for juvenile steelhead reducing the effectiveness of these predators.

The survival of juvenile steelhead was tested as part of a Hemlock Dam fish passage study in 1997. Hemlock Dam is located at RM 2 on Trout Creek and the USFS and USGS-CRRL developed a study to determine the passage routes and survival of steelhead passing Hemlock Dam. A total of 20 steelhead smolts captured at the Trout Creek screw trap were implanted with radio tags. These fish were handled in the same manner as fish used for mark recapture estimates. A total of 19 radio tagged smolts passed Hemlock Dam (Adams and Wieman, unpublished). Based on mobile radio tracking, it was determined that the single fish not passing the dam had likely regurgitated the tag. These results indicate that the survival of marked fish was 100%. In 1998 we tested the short-term survival of 33 steelhead smolts by holding them for a 24-hour period in live wells. The results indicated that survival was 100%, which is the same as previous years (Rawding 1997). The short-term survival for juvenile steelhead in the Situk River, Alaska used for trap efficiency studies was greater than 99% (Thedinga et al. 1994). Therefore, we assumed the survival of marked steelhead was 100% or equal to that of unmarked steelhead and we did not apply a correction factor to account for mortality bias between marked and unmarked fish.

(2) No Mark Loss - If undocumented mark loss occurs, it can lead to an underestimate of trap efficiency. Juvenile steelhead were tattooed with a Panjet inoculator (Hart and Pitcher 1969). Mark retention in juvenile chinook and coho salmon of 100% has been reported for fish held for more than 5 weeks in the hatchery (Hillman and Miller 1989, Thedinga and Johnson 1995). Rawding (1997) indicated similar results on the spring chinook held at Carson National Fish Hatchery. Three short-term mark retention tests were conducted in 1998 using steelhead. A total of 33 marked steelhead smolts were held for 24 hours in live boxes, with 100% mark retention. Based on these results, we believe there was no mark loss during this study.

(3) Proper Mark Recognition - In some cases recapture marks are not recognized leading to an underestimate of trap efficiency. This usually occurs when trap catches are high and samplers must examine many fish. Over the course of the season we handled a total of 5,815 juvenile steelhead, which is low compared to other juvenile trapping projects (Thedinga et al. 1994 and Sieler, 1997). Samplers checked for marked fish over a white background, where marks are more visible. In addition, we double marked 3,076 of 3,174 smolts. The marks consisted of the alcian blue tattoo and a blank wire tag inserted into the right cheek. Samplers were required to visually examine all fish for the tattoo and scan all fish for wire tags. Of the 633 recaptured wire tagged fish, all had visible alcian blue marks. This data supports that mark recognition during this experiment was 100%.

(4) Equal Catchability - Potentially marked fish may be attracted or repelled from the trap, resulting in positively or negatively biased trap efficiency. To test this bias, we compared lower Wind River trap efficiencies for marked fish from the lower Wind River and marked fish originating from three upstream traps recaptured at the lower Wind River trap. Our hypothesis was that marked fish from the lower Wind River should be recaptured at a lower rate than upriver marks if they avoid the trap or at a higher rate if they are attracted to the trap. Rawding (1997) reported that lower Wind River trap efficiencies during similar periods did not significantly vary between smolts marked at Trout Creek and the lower Wind River trap sites. In 1998, no significant differences were detected for marks originating from other traps over similar periods. Although these tests had low statistical power, they indicate that trap rejection or attraction is not a major concern at the lower Wind River site. Due to the high velocities at the three upriver traps, we believe that trap rejection or attraction is not a factor at the other traps.

(5) All fish have the same probability of capture in the first sample and the second sample is either a simple random sample, or if the second sample is systematic, marked and unmarked fish mix randomly. This assumption is difficult to validate using sample data alone and is likely to cause most the bias in the Petersen estimator. The probability that all fish have the same likelihood of capture in the first sample may not always be met due to differences in migrational patterns and trap efficiencies between different species, the same species at different lengths, life history stages, and/or physiological development, and hatchery and wild origin fish of the same species (Thedinga et al. 1994, Nicholson 1998, Seiler et al. 1997). To increase the same probability of first sample capture, trap efficiencies should be developed for homogeneous groups. To address this concern we separated steelhead into two homogeneous groups of steelhead parr and smolts and developed a separate estimate for each group.

To increase the probability of random mixing of marked and unmarked fish, release sites were located approximately one mile upstream of the traps. The lower Wind River release site is located 4 miles upstream due to limited access and the likelihood that complete mixing failed to occur in 1995, when the release site was located only ½ mile above the trap. However, factors such as changing stream flow, life history stage, water temperature, and photo period can influence fish migration and recapture rate (Seiler et al. 1997, Nicholson et al. 1998). It is possible that these factors combine to create trap efficiencies that change instantaneously. Some researchers have suggested that due to low numbers of daily recaptures and for the most part the slow change in these environmental conditions (flow and temperature) that it is appropriate to use weekly estimates (Dempson and Stansbury 1991, Thedinga et al. 1994, Nicholson 1998). In 1998, our marking schedule for smolts rotated every week and used three different fin

combinations to distinguish between traps. This allowed us to identify fish based on trap site and marking period. Since the number of fin mark combinations is limited, the same marks were repeated every 21 days. Previous years' data indicated that the maximum migration time for Wind River steelhead juveniles between traps was 3 weeks, so the three week rotation is consistent with our objective of identifying fish by trap site and marking period (WDFW, unpublished data).

Seiler et al. (1997) proposed an alternative to the weekly trap efficiency method by developing an equation that defines the relationship between trap efficiency and flow through the use of marked fish over the entire range of observed discharge. Due to the single releases of a large number of marked fish required to develop this equation, this methodology is usually used for more abundant anadromous salmonids such as chum, pink, coho, chinook, and sockeye salmon. It has limited use when sampling smaller populations such as Wind River steelhead, because not enough fish can be captured and marked in a single day to routinely achieve the five or more recaptures recommended by Schwarz and Taylor (1998).

An independent method of estimating smolt production was proposed by Seiler et al. (1997) and termed "back calculation". The back calculation method occurs when smolts are wire tagged and returning adults are sampled for wire tags. The number of outmigrating smolts is determined from Chapman's modification to the Petersen estimate $N = ((M+1)(C+1))/(R+1)$, where N is the total number of smolts passing the lower Wind River trap, M is the number of wire tagged smolts, C is the number of adults recovered and examined for tags, and R is the number of recovered wire tagged adults. This method avoids the potential problem of instantaneous changing trap efficiencies. In 1998 we wire tagged 3,076 steelhead smolts. Adult steelhead entering the Shipherd Falls trap (RM 2) will be scanned for wire tags, and smolt estimates from the back calculation method will be compared against the trap efficiency method.

Quality of Habitat

Gibbons et al. (1985) developed a Parr Production Index (PPI) model to estimate summer carrying capacity of age 1+ steelhead parr based on measured stream gradient zones for western Washington rivers that were seeded at or above Maximum Sustainable Harvest and under average 1980's habitat conditions. Lucas and Nawa (1985) used this model and actual tributary densities from Crawford (1985) to develop steelhead parr production estimates at maximum sustainable yield for the Wind River basin. Using the 40% steelhead parr to smolt survival from Johnson et al. (1988), these parr production estimates from PPP were converted into smolt production estimates. Johnson et al. (1988) developed an alternative model called the Gradient Area Flow Methodolgy (GAFM) built on the Gibbons et al. (1985) methodology but improved by using continuous gradient and flow measurements to develop parr estimates, and adjusted the steelhead productivity by smolt age and rainbow trout abundance. We applied the GAFM model to the Wind River with the most current steelhead distribution. Smolt production estimates using both of these models are shown in Table 6.

Table 6. Comparison of WDFW smolt model outputs with observed Wind River smolt production, 1995-98.

| Production Zone | Smolt Production Goal using PPI | Smolt Production Goal using GAFM | 1998 Smolt Estimate | 1997 Smolt Estimate | 1996 Smolt Estimate | 1995 Smolt Estimate |
|----------------------------|---------------------------------|----------------------------------|---------------------|---------------------|---------------------|---------------------|
| Wind Basin | 23,497 | 31,473 | 24,316 | 15,619 | 11,326 | 8,330 |
| Trout Creek | 4,183 | 6,368 | 4,030 | 2,171 | 1,111 | 1,951 |
| Panther Cr. | 2,778 | 4,809 | 1,394 | ~1,000 | ~1,000 | ~1,000 |
| Upper Wind | 7,887 | 6,774 | 2,580 | Not Available | Not Available | Not Available |
| Main. Wind between 3 traps | 16,536 | 20,296 | 18,892 | 12,448 | 9,215 | 5,379 |
| Main. Wind between 4 traps | 8,649 | 13,522 | 16,312 | Not Available | Not Available | Not Available |

The accuracy of these models for the Wind River is unknown due to lack of a long-term data series. The only basin in southwest Washington with a data set to examine the utility of these models is the Kalama River, where annual adult population monitoring has been ongoing since 1977 and the smolt population has been intermittently monitored since 1980. The GAFM methodology compared favorably with the 1980's Kalama River smolt production estimates (WDFW et al. 1990). The PPI methodology is in the ballpark for Kalama River adult escapement goals at MSY (WDFW, unpublished data). Many factors effect smolt production including the quality of habitat, number of spawners, reproductive success of the spawners, and ecological interactions with other fish in the basin. Because these factors are intrinsically variable and poorly documented in the Wind River, the smolt production data is not presented here to validate the models, but as a gross measure of habitat quality within the basin.

As noted, these models were developed from age 1+ steelhead parr snorkel observations under average habitat conditions during the mid- 1980s for stream reaches that were above MSH seeding. In addition, these stream reaches typically contained multiple species. Therefore, the smolt production in a given stream reach can be higher than the model predicted due to excellent habitat, lack of competition from other species, or if escapements are managed for the maximum number of spawners. In this analysis, we assumed that stream reaches with smolt production equal to or greater than the model outputs are likely candidates for habitat protection, while reaches with smolt production lower than the model outputs are likely candidates for stream restoration.

We observed the highest smolt production from the entire basin and from individual traps in 1998 and will use that as the standard to prioritize habitat restoration areas by comparing actual and predicted smolt production. Basin-wide smolt production was 103% of PPP and 77% of GAFM. The smolt production for the area between the four traps, mainly in the mainstem Wind River between Trapper Creek and the Little Wind River, was 188% and 120% of PPP and GAFM, respectively. Based on the observed smolt production this steam reach would receive an excellent rating. Most of this stream reach is dominated by the “Wind River Canyon”, which is a

Rosgen “B” channel characterized by riffles with infrequent pools and a moderate slope (2-4 percent) (Rosgen 1994). The substrate in this reach consists almost entirely of large boulders and large cobble. Rich et al. (1992) indicated that undisturbed B channels would provide excellent steelhead 1+ parr-rearing habitat. Except for the scour from high flows and past splash damming, the habitat in this reach is likely the least altered relative to historic conditions.

A substantial reach within the section above the canyon is a Rosgen “C” channel. These channels typically meander through a valley and are characterized by deposition of fine materials and lower velocity, with gradients of less than 1.5 percent (Rosgen 1994). The 1+ parr rearing habitat quality in this reach is likely less than that of the canyon due to steelhead preference for B channels (Scully and Petrosky 1991) and habitat degradation. Habitat quality in this section is degraded by warm water temperatures, lack of large woody debris, sedimentation, and peak flows (USFS 1996). Past habitat restoration projects in which large woody debris was added to create additional rearing and spawning area, have had limited success due high stream discharge. If instream projects are to be undertaken, projects should be better designed so that they will be cost effective and remain functional for longer durations. Less invasive projects such as riparian plantings, and road decommissionings that restore ecosystem function should be considered.

In 1998 the Trout Creek smolt production above the trap located at River Mile 2 was 4,030 smolts or 96% of PPP and 63% of GAFM. This stream reach would receive a good to fair rating based on measured smolt production. Past logging practices have led to increased peak flows, increased sediment transport, increased temperature, and decreased instream habitat by the removal and lack of recruitment of large woody debris (USFS 1996). The USFS, which is the only landowner above the trap, has invested with other partners over \$600,000 in the last five years to improve the quality of fish habitat (Brain Bair, USFS personal communication). The full recovery of fish habitat can only occur when the ecosystem recovers, which will take decades. The most cost effective instream habitat restoration projects have been identified and implemented. Future projects should focus on actions that will restore ecosystem function such as road decommissionings, riparian plantings, and land management actions that reduce peak flows.

The upper Wind River above Trapper Creek produced 2,580 smolts in 1998, which is 33% and 38% of the PPP and GAFM goals, respectively. The quality of habitat based on smolt production ratings would be considered poor. The smolt production potential based on these models is between 6,874 and 7,887 and successful habitat protection and restoration projects in this reach would have significant benefits for steelhead. However, a total of 6,162 steelhead parr migrated past the trap in 1998, which is a high number of spring migrants for the Wind River. This combination of parr and smolt data indicate the possibility that 1+ parr habitat is lacking in this area.

This area is managed by the USFS and has been identified as the next major emphasis area for habitat restoration within the Wind River basin. Restoration projects that focus on restoring ecosystem function will improve water depth and cover, which have been shown to be important factors in 1+ steelhead microhabitat selection (Beecher et al. 1993, Cramer et al. 1997). Projects that reduce cobble embeddness and increase large woody debris will improve instream cover, and a reduction in width to depth ratios will provide the deeper pools that 1+ parr prefer. However, since this reach of stream serves as an important incubation and age 0 rearing area, habitat improvements for 1+ parr should not come at the expense of incubation and age 0 rearing.

Smolt production in Panther Creek was only 50% of PPP and 29% of GAFM in 1998 (Table 6). This results in a poor rating for habitat quality for smolt production. However, we

have consistently observed the lowest wild steelhead redd densities in this creek as compared to upper Wind River and Trout Creek, indicating that the low smolt production in Panther Creek may be significantly influenced by low escapement. The potential increase in smolt production from predicted to observed is between 1,000 and 3,000 smolts. Since this potential increase is less than the upper Wind River, restoration efforts in this basin should be a lower priority than the upper Wind River. As in the case of the upper Wind River, parr production from this stream reach was 6,693 indicating the possibility that habitat for 1+ parr is limiting. Past logging practices have led to increased peak flows, increased sediment transport, and decreased instream habitat through the removal and lack of recruitment of large woody debris (USFS 1996). A focus on habitat restoration to protect and restore ecosystem function is recommended.

Importance of Smolt and Parr Production Data

The limited amount of data ($n = 4$) from the Wind River juvenile outmigrant monitoring program indicates that parr and smolt production from the basin and from key production areas is highly variable between years. Juvenile production estimates are a function of adult escapement, reproductive success of hatchery and wild spawners, capacity and productivity of habitat, and natural environmental change. Accurate measurement of these parameters is needed to discern effects of the completed and proposed habitat modification on natural steelhead production. Reeves et al. (1992) indicated that it could take ten years or more before full biological and physical responses to instream habitat restoration projects are realized. Preliminary data from Trout Creek indicate a positive trend in smolt abundance, with smolt production increasing from 1,951 in 1995 to 4,030 in 1998 after habitat restoration programs were initiated in the early 1990s. Baseline data was collected in 1998 and will be collected in 1999 prior to the planned habitat restoration effort in the upper Wind River. Before, we can examine the effectiveness of habitat restoration on steelhead smolt production, more data are needed in Trout Creek and the upper Wind River sub-watersheds.

The current smolt and parr production data has been very useful in other areas. First, the data collected from four years of juvenile steelhead monitoring is being used to develop a description of movements of wild Wind River summer steelhead adults and juveniles through time and space (Rawding 1999). A draft report in preparation to provide scientific background to use summer steelhead as an indicator species to assess environmental conditions of the Wind River based on the assumption that this species is sensitive to a wide variety of ecosystem conditions. The assessment will be completed through an Ecosystem Diagnosis and Treatment approach following the principles in Lestelle et al. (1996).

Smolt monitoring is an important element for a Wind River steelhead extinction risk assessment. Wild adult steelhead run size and escapement data indicate the stock has been able to replace itself at only low abundance levels or not replace itself at all (WDFW 1997). This situation is unhealthy and indicates a high risk for extinction (Chilcote 1998). However, Wind River smolt data indicate that freshwater production is adequate for adult replacement or even rebuilding given average survival in the Columbia River mainstem and ocean productivity. When smolt and adult data are analyzed together, they indicate that wild steelhead spawner abundance is being greatly influenced by factors outside of the Wind River Sub-basin such as survival in the Columbia River migration corridor and/or in the ocean. Fisheries agencies have initiated captive broodstock (e.g., IDFG - Redfish Lake sockeye) or supplementation (e.g., WDFW - upper Columbia River steelhead) programs to prevent extinction of anadromous salmonid populations. However, the effectiveness of captive broodstock and supplementation programs to recover at risk populations is unproven and these programs present significant risks

(Miller et al. 1990). Therefore, WDFW has advocated a cautious approach for supplementation (WDFW 1997). Given the current natural smolt production in Wind River, we feel that intervention through supplementation or captive broodstock programs is not presently needed. However, continued declines in adult escapement or a sharp decline in smolt productivity would cause us to re-evaluate this situation. Therefore, continued smolt production monitoring along with adult monitoring is needed to update risk assessments for Wind River wild steelhead.

Conclusions and Summary

The estimated wild steelhead smolt production from the Wind River basin and key production areas in 1998 was the highest on record since monitoring began in 1995. The basin smolt production was estimated at 24,316 fish.

The accuracy and precision of smolt and parr production estimates were improved in 1998 due to better site selection, which improved trap efficiencies. The estimates at the lower Wind River were also improved due to the capture of additional marked fish initially captured at the upper Wind River trap. The coefficient of variation (CV) was also improved over previous years and was measured at less than 10% in three of the four trap sites.

The output from two WDFW steelhead production models was compared to the 1998 smolt outmigration. Predicted and observed smolt productions were similar for the lower Wind River and Trout Creek. The largest discrepancy of predicted versus observed smolt production occurred in the upper Wind River and in Panther Creek. We observed the highest outmigration of parr from the upper Wind and Panther Creek. Degraded habitat for 1+ parr in these reaches may be a factor influencing the high 1+ spring parr migration and the low smolt yield from these areas.

Due to the similarity between observed and predicted smolt production, there should be a focus on protecting habitat in the lower Wind River and Trout Creek. Due to large differences in predicted versus observed smolt production and the large parr migration observed in the upper Wind River and Panther Creek, these reaches should be targeted for habitat restoration. Restoration activities that improve age 1+ parr habitat would provide the most benefit, but care should be taken not to degrade incubation and age 0+ rearing habitat. Therefore, projects that restore ecosystem function should be given highest priority.

Smolt production is influenced by the number and composition of adult spawners, along with habitat quality and quantity. Smolt production over the four years of this study was highly variable. These variations in smolt production make it difficult to discern short-term effects of habitat restoration. At a minimum, long-term smolt, adult, habitat, and environmental monitoring are necessary to determine the effects of restoration activities and to assess extinction risk.

Acknowledgments

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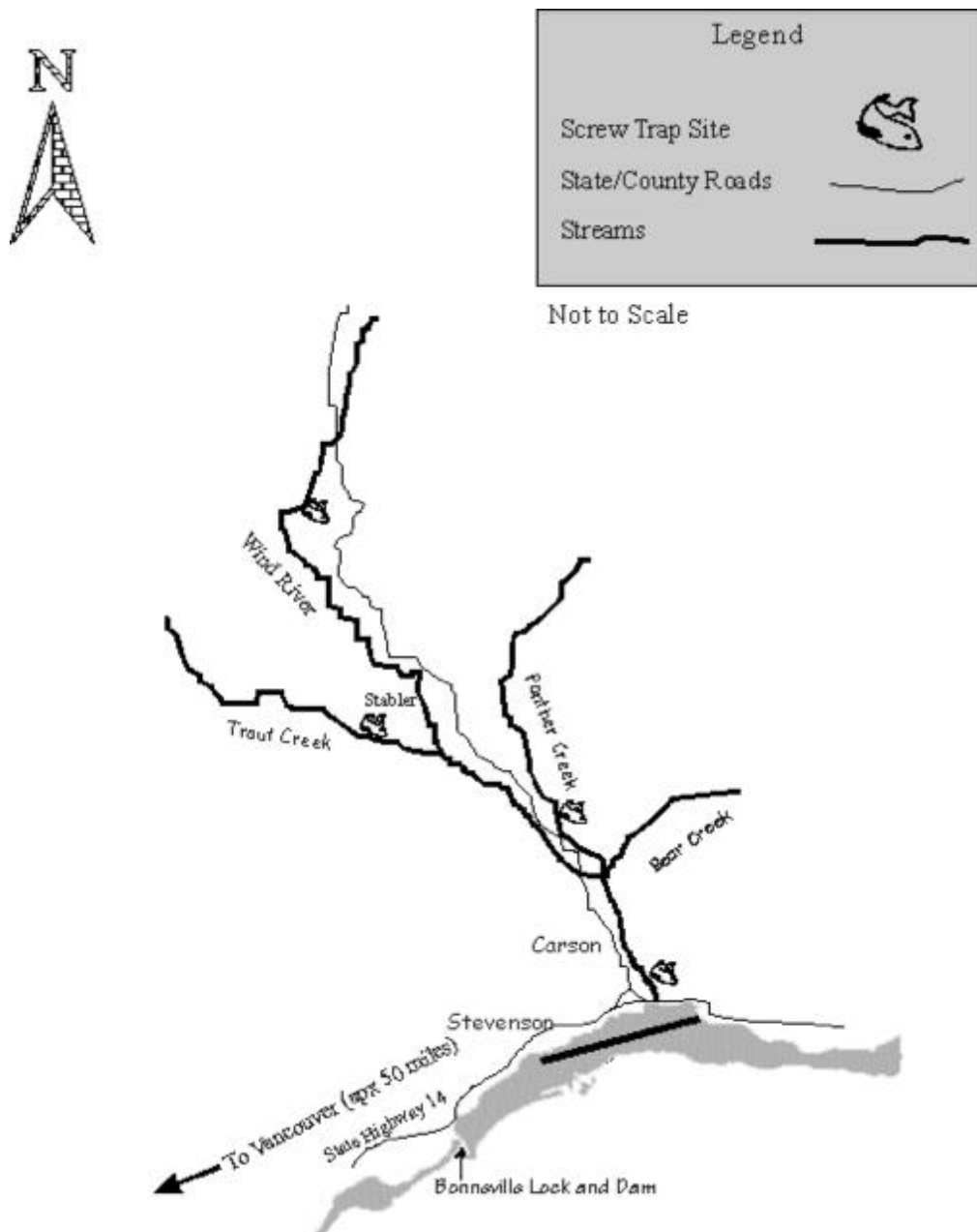


Figure 1. Sketch of the Wind River basin showing screw trap locations. Skamania County, Washington, 1998.

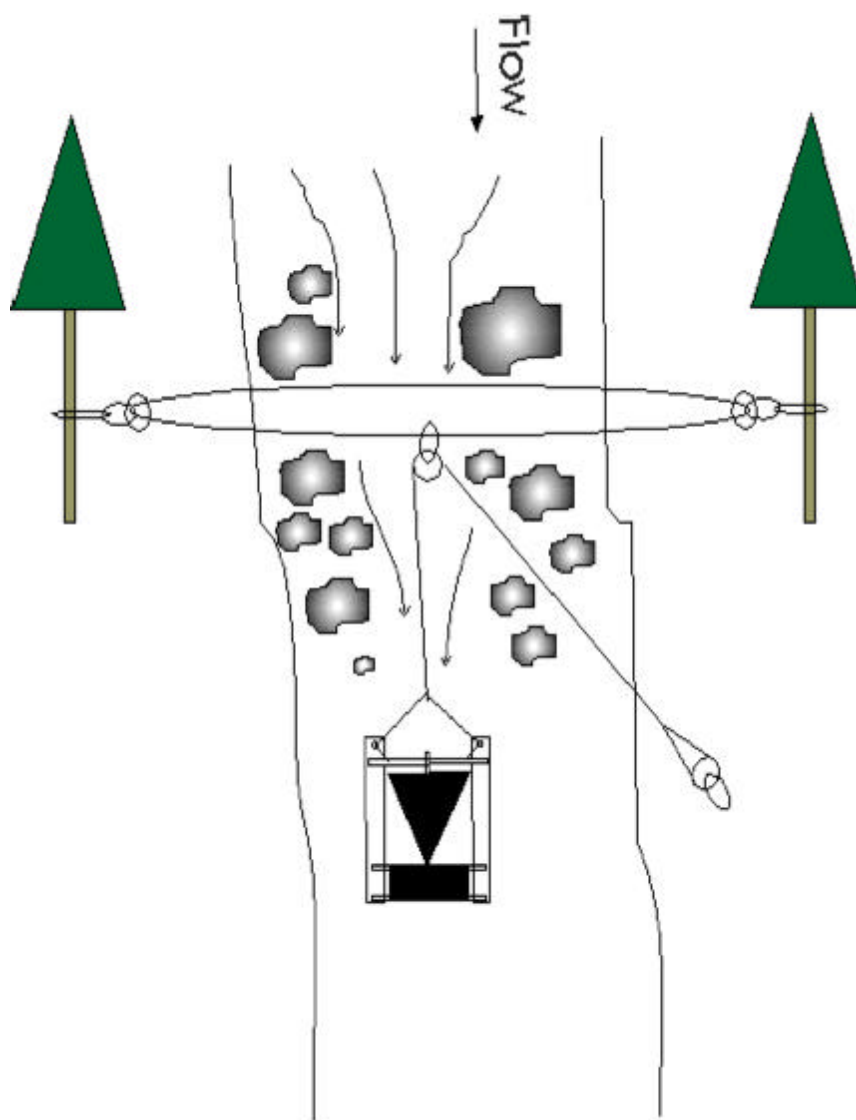


Figure 2. Sketch of typical screw trap installation with adjustable cable system and trap placement below a channel constriction.

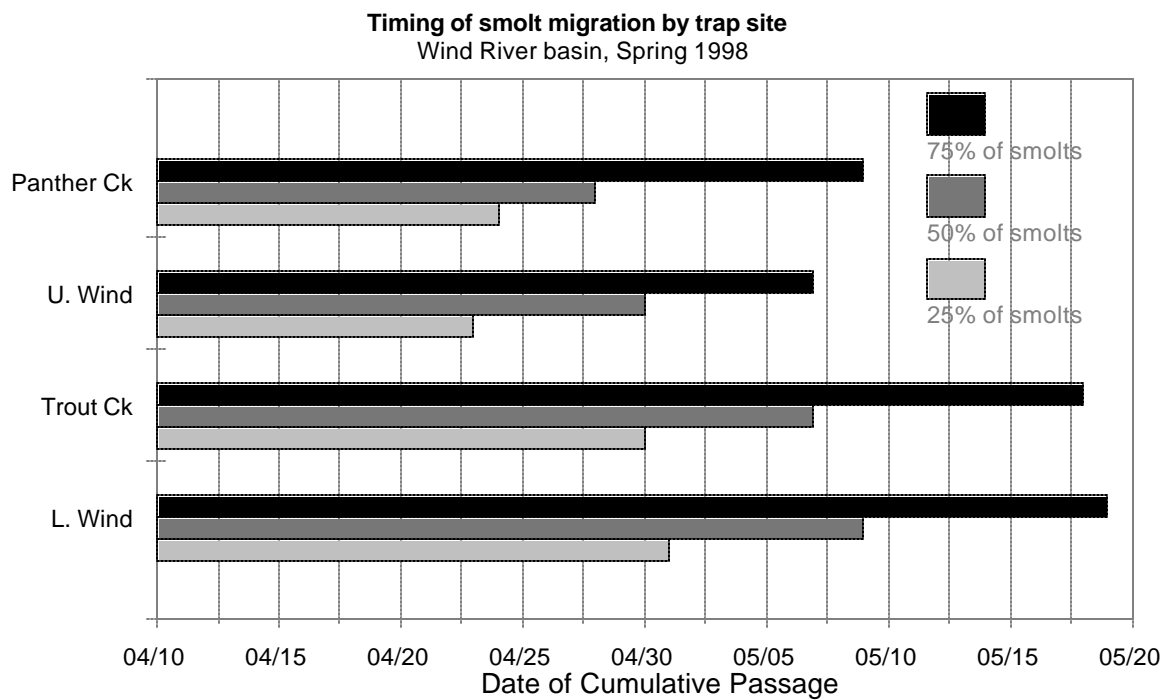


Figure 3. Cumulative steelhead smolt outmigration timing in the Wind River Basin, Spring 1998.

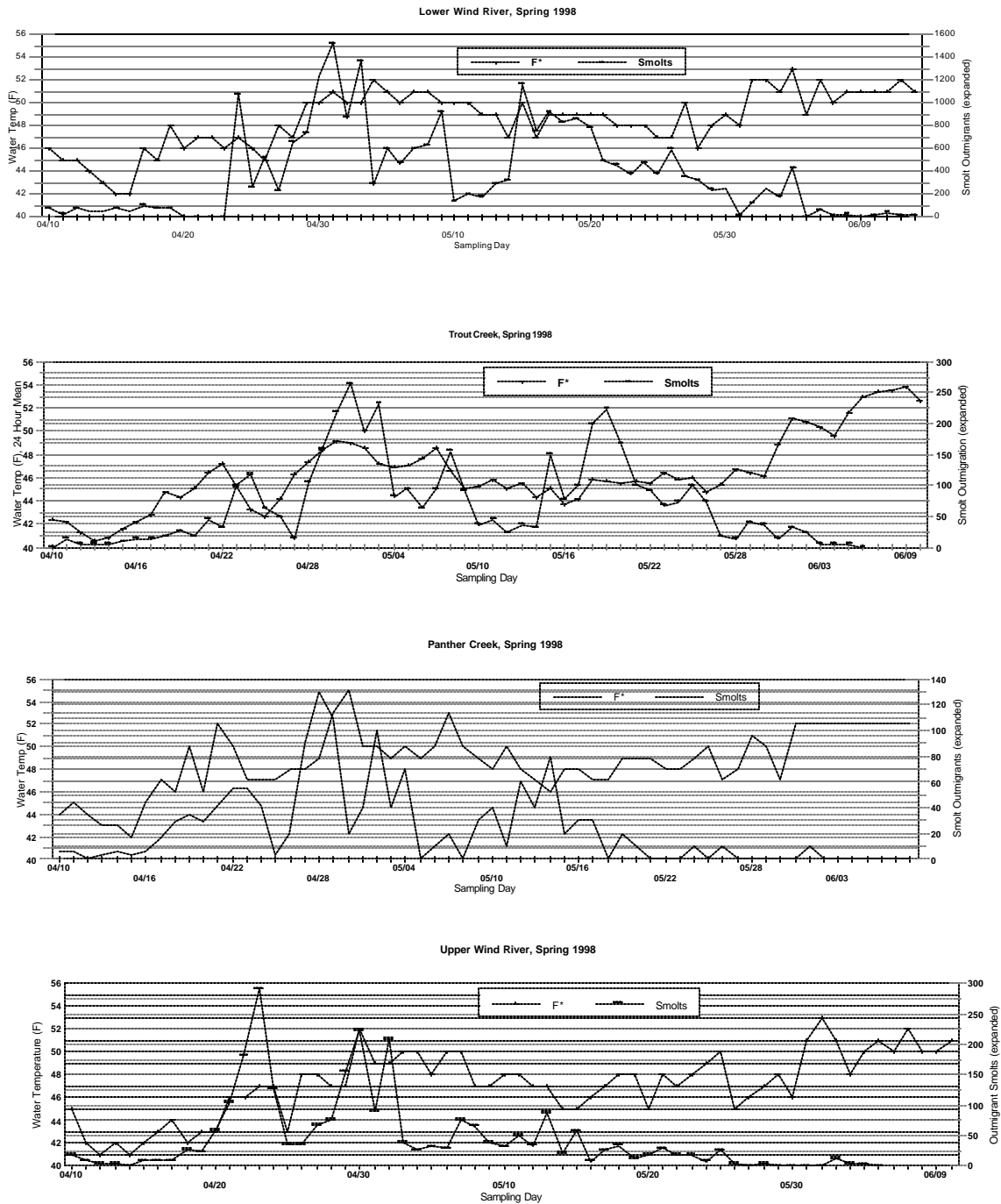


Figure 4. Daily steelhead smolt yield and water temperature at four trap sites in the Wind River Basin, Spring 1998.

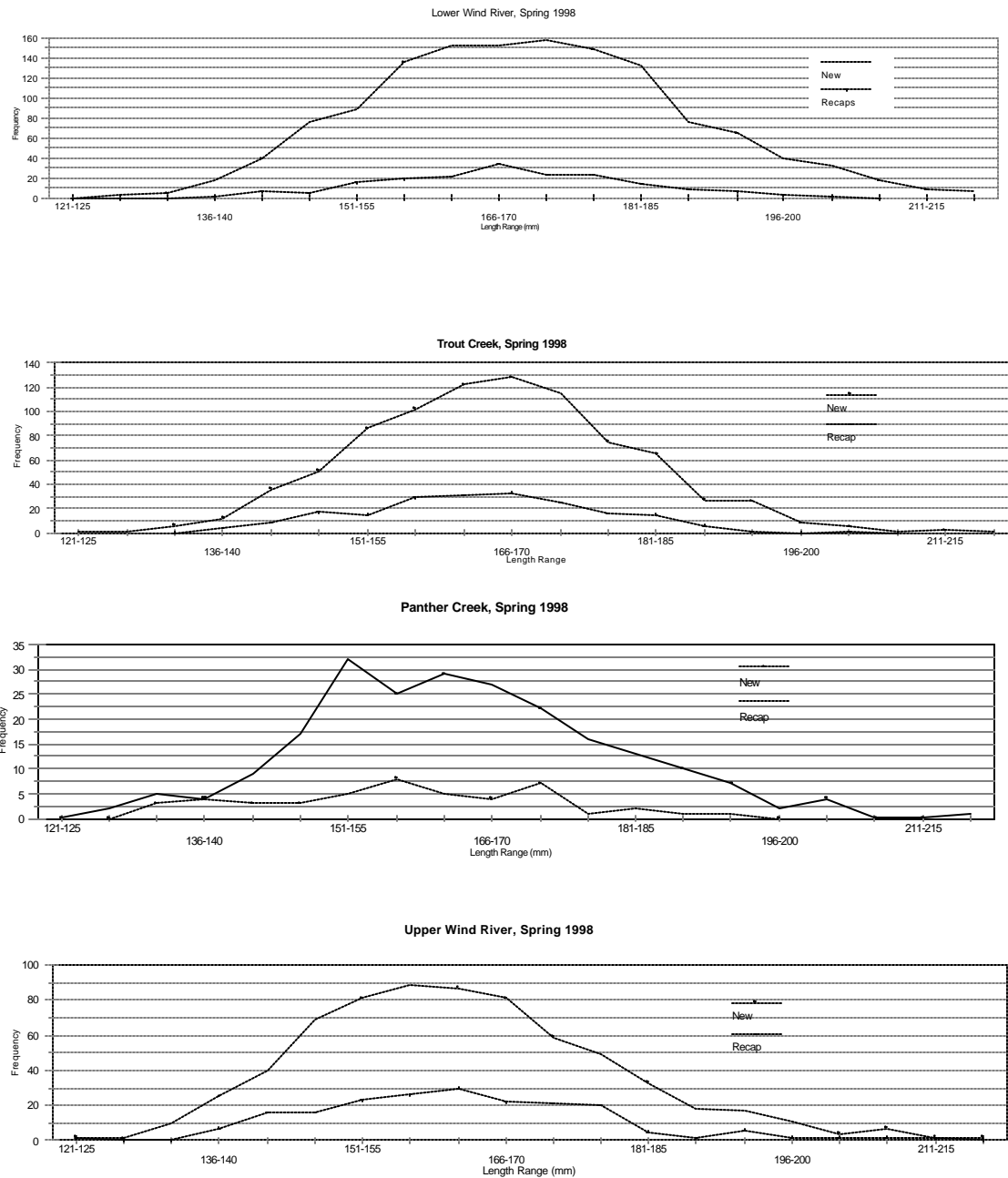


Figure 5. Length Frequencies of new and recaptured smolts in the Wind River basin by trap site, Spring 1998.

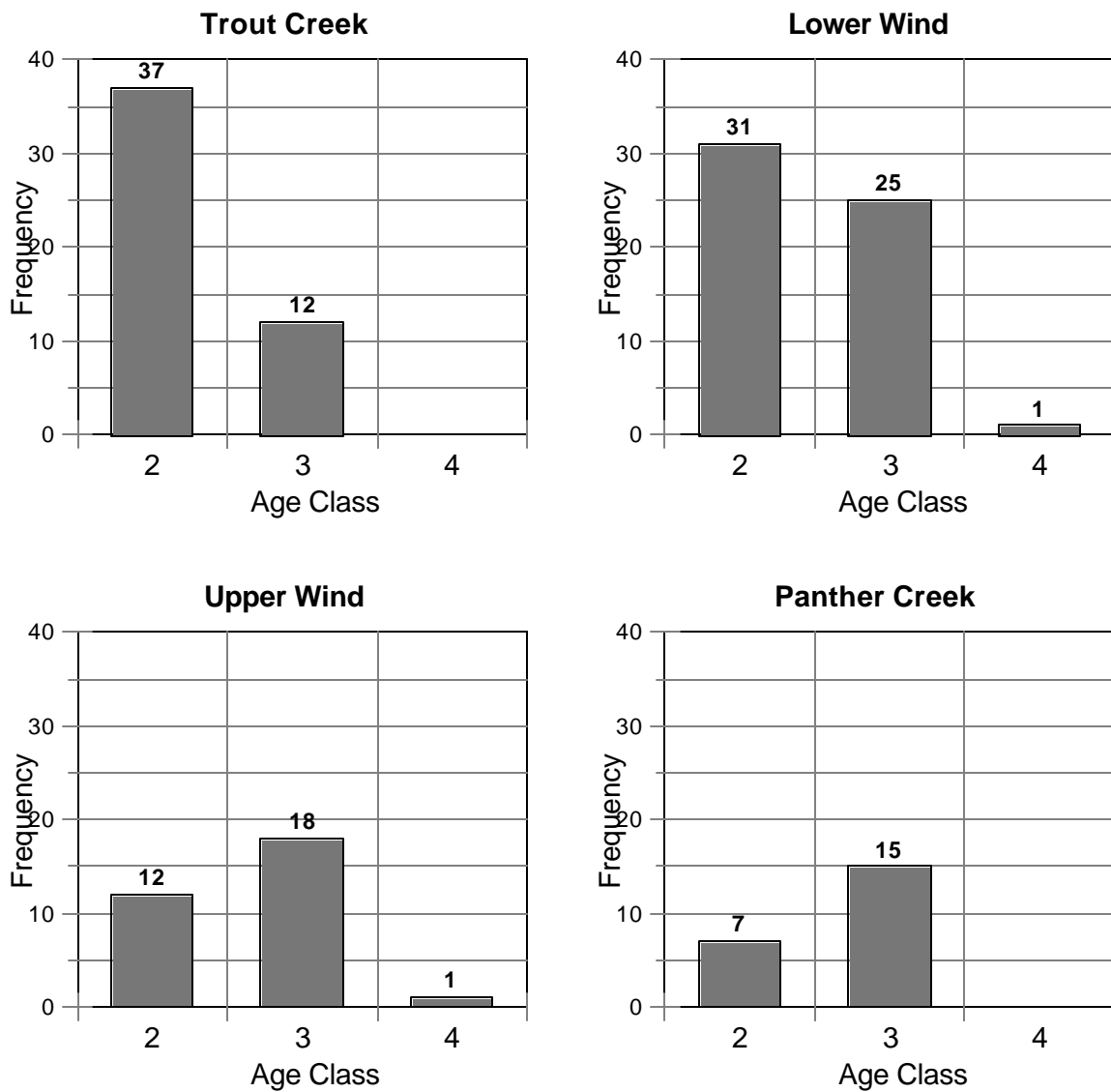


Figure 6. Steelhead smolt age frequencies by trap site. Wind River basin, Spring 1998.

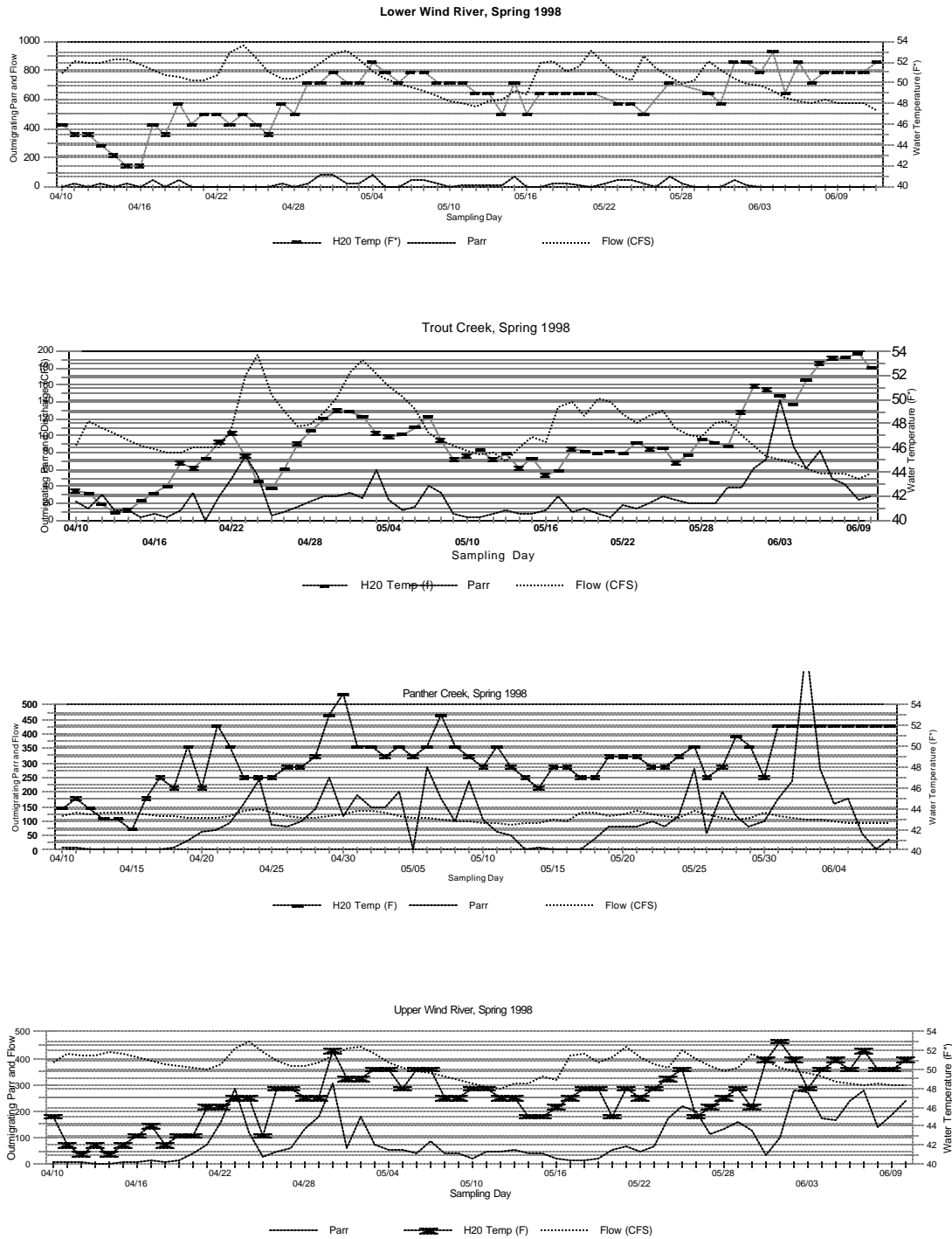


Figure 7. Daily parr yield, stream flow and stream temperature by trap site. Wind River basin, Spring 1998.

Report E: Juvenile Steelhead and Rearing Conditions

Wind River Watershed Project

1998 Annual Report

November 1999

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Introduction

As members of the Wind River Restoration Team since 1994, personnel from the Columbia River Research Laboratory (CRRL) of the U.S. Geological Survey's (USGS) Biological Resources Division (BRD) have had a primary role in a multi-agency effort to restore steelhead to the Wind River subbasin. Consistent with the mission of the CRRL and BRD, the role served has included research, evaluation, and monitoring of steelhead populations in the subbasin. To date we have concentrated much of our efforts on the parr stage of the steelhead life history. We have also been generating information to understand the factors that contribute to production of steelhead and to gauge historical and probable future range of variation.

This report covers work completed under Tasks 3a of Objective 3 as stated in the Statement of Work (SOW) submitted in April 1998 by the USGS-CRRL. The task is also listed in the Master Statement of Work (MSOW) submitted in May 1998 by the Underwood Conservation District, which is the contact agency for the overall project.

Our stated objective was to determine productivity and life history of juvenile steelhead in the Wind River watershed (Figure 1). To accomplish this, we conducted field sampling to derive population estimates for steelhead parr and other salmonids in several tributary streams of the Wind River subbasin. Surveys focused on formerly established index reaches as well as new index reaches, within Panther Creek and Trout Creek. In addition, we measured the important habitat factors of water temperature and stream flow at numerous sites.

Much of this work is ongoing. We are currently conducting our second field season under BPA funding. This report focuses on comparing the annual data on juvenile steelhead populations, stream temperatures, and stream flows collected in 1998 with those data available from previous years. The primary focus to the analysis to date has been on data from Trout Creek, where runs of adult steelhead have dropped from a few hundred a year in the 1980s to under 30 per year in the 1990s (USFS 1996, see also Section D of this document). These data and analyses are expected to help us delimit current and potential productivity levels and understand limiting factors within the context of annual variation.

Methods

To obtain estimates of fish density and biomass, we conducted habitat surveys of sampling sites during summer 1998. We electrofished a systematic sample of habitat units within strata of habitat types (e.g., pools, glides, and riffles). Habitat units chosen for sampling were blocked off with nets to insure no movement into or out of the unit during sampling. A backpack electrofisher was used to conduct two or more passes under the removal-depletion methodology (Zippin 1956, Bohlin et al. 1982, White et al. 1982). The field guides of Connolly (1996) were used to insure a controlled level of precision in the population estimate (CV < 25% for age-0 and CV < 12.5% for age-1 or older juvenile steelhead) was achieved within each sampling unit for each salmonid species steelhead/rainbow trout, brook trout) and age group (two age groups). These methods were chosen specifically to minimize the number of units sampled by electrofishing and to minimize the number of electrofishing passes conducted. This approach serves to lessen the chance that individual fish will be exposed to potentially harmful effects of electroshocking while insuring a high degree of precision in our estimates.

Additional fish surveys were conducted in larger streams (3rd order or larger) by snorkeling. To calibrate snorkel estimates, we snorkeled within pools after block nets were placed over the inflow and outflow to prevent fish from entering or exiting. We then electrofished these units with three or more removal passes to ensure that most fish in the unit were caught and that a precise estimate could be derived (CV < 12.5% for age-0 and CV < 5% for age-1 or older juvenile steelhead). We will use the ratio of the two estimates as a calibration factor for our snorkeling counts. Results of these efforts are not reported here; they have yet to be fully analyzed.

A network of 21 continuous recording thermographs were placed and maintained in the Wind River system (Table 1). All units deployed by CRRL were Optic StowAway Temp devices from Onset Computer Corporation (OCC). Before deployment, the units were tested at our lab for accuracy and for adequate response time to change in temperature as per instructions of OCC's operating manual. Temperature data has been and continues to be downloaded from these devices at least two times a year with at least a Spring and Fall download date. Data from these thermographs were last downloaded in April 1999.

Thermographs were set to record water temperatures every two hours. The daily mean temperature was calculated as the mean of the resulting twelve readings that were recorded each day. The minimum and maximum temperatures were derived by using the minimum and maximum readings from the twelve readings taken in a day.

Eight flow monitoring stations were visited periodically throughout summer 1998. While a few of these stations were new for 1998, some of them were established in 1996 or 1997 under other funding sources (Table 2).

Results

A total of 12 stream reaches or sections were surveyed for juvenile steelhead in summer 1998. Some of these streams received two surveys, which resulted in 14 surveys conducted. These surveys are an extension of a developing matrix of similar surveys (Table 3) conducted in 1984 (Crawford et al. 1985), 1996 (Connolly 1997), and 1997 (Connolly et al. 1997).

In all streams sampled from 1996-1998, the fish assemblage has been limited to one, two, or three species in any one stream (Table 4). A total of four fish species have been found in sampled areas: steelhead/rainbow trout (*Oncorhynchus mykiss*), shorthead sculpin (*Cottus confusus*), brook trout (*Salvelinus fontinalis*), and chinook salmon (*Oncorhynchus tshawytscha*). Of these four species, only the steelhead/rainbow trout and the shorthead sculpin are considered to be native to the Wind River subbasin above Shipherd Falls (Connolly 1995).

Seven electrofishing surveys were conducted in summer 1998 (Table 5). Population estimates have been derived for all stream reaches sampled in the Trout Creek system, and will be derived for the remaining areas (Big Hollow Creek and two reaches of Eightmile Creek) in the near future. The other seven population surveys were conducted by snorkeling. Five 100-m reaches were snorkeled in the mainstem Trout Creek (Table 5), while pools in two 1000-m reaches were surveyed by snorkeling in Paradise and Trapper creeks. Data from these snorkel surveys have been entered, and population estimates will be derived in the near future.

Population estimates (no./m) for age-0 steelhead in 1997 and 1998 in upper reaches of the Trout Creek watershed were generally lower than those in 1984 and 1996 (Figure 2). In contrast, Martha Creek, which is lower in the watershed below Hemlock Dam, supported high densities

and biomass (g/m^2) of age-0 steelhead in 1998 relative to other sampling years and compared to stream reaches sampled in the upper Trout Creek system.

In Crater and Martha creeks, biomass estimates for age-1 or older steelhead in 1998 were similar to those in 1984, but higher than those sampled in 1996 and 1997 (Figure 3). The populations of age-1 or older steelhead in Trout Creek watershed showed relatively minor fluctuations during 1996-1998 except in Martha Creek, which in 1998 supported less than half the population it supported in 1997.

In the reaches that supported brook trout (Crater Creek and mainstem reaches of Trout Creek), brook trout numbers and biomass showed an increase in Crater Creek for 1998 over 1996 and 1997, but were similar to the populations and biomass found in 1984 (Figure 4). Brook trout population and biomass in the mainstem Trout Creek near the Road 33 bridge in 1998 were about half that found in 1984. The brook trout contribution to the biomass of total salmonids shows an increasing trend with year from 1996-1998 in all three reaches sampled (Figure 5). In a mainstem Trout Creek section just below the Road 33 bridge, brook trout contribution to total salmonid biomass was higher in 1996-1998 than in 1984, but in Crater Creek the brook trout contribution was lower in 1996-1998 than in 1984.

Relatively high water temperatures were recorded during summer at all tributary sites monitored in the Trout Creek and Panther Creek watersheds. The number of days that water temperatures exceeded 16, 18, and 20°C tended to be more numerous in 1998 than in 1997 (Table 6). In contrast to the Trout Creek mainstem, where these higher temperature levels were achieved in downstream sites by RKM 9.0, the mainstem Panther Creek never exceeded 16°C at RKM 4.0. The Trout Creek mainstem showed considerable warming in 1997 and 1998 between a site just above Crater Creek (RKM 12.2) and a site located 3.2 km downstream at the Road 43 bridge (RKM 9.0), which is below the mouth of Layout Creek. Associated with this warming trend was a large increase in the diel temperature range (Figure 6). As suggested by the number of days exceeding 16°C (Table 6), considerable additional warming of Trout Creek takes place between the Road 43 bridge and the inflow to Hemlock Lake.

In lower Eightmile Creek (at RKM 0.2), a tributary of Panther Creek that is listed on the State of Washington's 303(d) list, water temperature often exceeded 16°C during 1997 and 1998, but it never exceeded 20°C (Table 6). In contrast, an upstream site in Eightmile Creek, just 0.6 km above its mouth, water temperature did not exceed 16°C in 1997 and exceeded it on only two days in 1998.

The lower stream temperatures recorded in summer 1997 relative to that of 1998 coincided with higher stream flows for 1997 than in 1998. The 1997 flows of tributary streams in Trout Creek (Figure 7) and Panther Creek (Figure 8) were also higher than those of 1996. Lowest flows of for the years 1996-1998 generally occurred in August and September.

Discussion

Although numbers and biomass of juvenile steelhead varied considerably from year-to-year for 1996-1998 in sampled areas of the Trout Creek watershed, these numbers and biomass were not consistently different than those reported by Crawford et al. (1985) for summer 1984. Because adult steelhead returns in the early 1980s were several fold higher than those in the mid-to-late 1990s, this result was not expected. It is too early to tell if this index of juvenile production is an indication of potential for higher runs of steelhead to Trout Creek in the near

future or whether survival has decreased for some part of their life phase spent outside the Trout Creek watershed (i.e., mainstem Wind River, mainstem Columbia River, estuary, or Pacific Ocean). Lack of historical data on juvenile production will always be a problem in this analysis, but current annual assessments of redds, juveniles, smolts, and adults are expected to help us determine critical life-history phases.

Numbers of age-0 steelhead in index reaches above the smolt trap site in Trout Creek were lower in 1997 relative to that in 1996, which coincided with a decided drop of smolts migrating past the trap area in 1998 relative to that in 1997 (see Report D of this document). This relationship indicates that these index sites could be useful monitoring and predictive tools for smolt production.

The relationship between smolt numbers and numbers of age-1 and older steelhead in the upper Trout Creek watershed was not clear. It may well be that many age-1 and older steelhead emigrate to mainstem areas of Trout Creek and Wind River (see Report B of this document) for rearing. To understand the importance of this life history pattern, we will be initiating snorkeling for juveniles in mainstem reaches of Trout Creek and Wind River during the 1998 field season. In addition, we will be placing PIT tags in age 1 and older steelhead in August-October 1999 to track movements of individual fish. Because these movements as well as survival may be influenced by annual differences in stream temperatures and flows, we continue to monitor these important habitat factors.

One potential reason for the recent decline of steelhead in the Trout Creek watershed is negative interactions of juvenile steelhead with brook trout. The negative effect that brook trout have on rainbow trout is well documented (Newman 1956, Larson et al. 1995). Brook trout were first introduced to Trout Creek watershed in the 1930s and continued to be planted in the watershed through the early 1980s (USFS 1996). Results from our sampling in upper Trout Creek watershed in 1996-1998 compared to results in 1984 by Crawford et al. (1985) do not indicate that brook trout populations have had an increase in density concomitant with a decrease in steelhead runs to Trout Creek. However, if the recent trend during 1996-98 for the brook trout to account for an increasing amount of total salmonid biomass continues, then brook trout populations may become more of a concern for fishery managers.

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Table 1. Thermograph locations within the Wind River subbasin. Sites are listed from upstream to downstream within a subbasin. Coordinates are from a hand-held Global Positioning System (GPS) using North American Datum 1927.

| Watershed | GPS reading | | Elevation (ft) | Distance upstream from mouth (km) | Date start (mm/yy) | Date end (mm/yy) |
|----------------------------------|------------------|--------------|-------------------|-----------------------------------------|--------------------------|------------------------|
| Subwatershed Subdrainage | North | West | | | | |
| Upper Wind River | | | | | | |
| Paradis e Cr. | 45° 57.149' | 121° 56.400' | 1,760 | 1.0 | 10/98 | present |
| Trapper Cr. | 45° 53.431' | 122° 00.593' | 1,360 | 1.5 | 10/98 | present |
| Big Hollow Cr. | 45° 55.444' | 121° 58.916' | 1,460 | 0.5 | 10/98 | present |
| Wind River--upper | 45° 52.501' | 121° 58.629' | 1,090 | 32.3 | 10/98 | present |
| Trout Creek | | | | | | |
| Trout Cr.--upper | 45° 50.798' | 122° 01.962' | 1,920 | 12.2 | 12/96 | present |
| Crater Cr. | 45° 50.769' | 122° 01.997' | 1,920 | 0.2 | 12/96 | present |
| Trout Cr.—33 bridge | 45° 50.727' | 122° 01.987' | 1,900 | 12.0 | 12/96 | present |
| Compass Cr. | 45° 50.427' | 122° 02.051' | 1,900 | 0.2 | 12/96 | present |
| Trout Cr.--upper OG ^a | 45° 49.867' | 122° 01.428' | 1,835 | 10.6 | 11/97 | present |
| Layout Cr. | 45° 49.776' | 122° 01.525' | 1,830 | 0.1 | 11/97 | present |
| Trout Cr.--lower OG | 45° 49.656' | 122° 01.278' | 1,810 | 9.6 | 11/97 ^c | present |
| Trout Cr.--43 bridge | 45° 49.320' | 122° 00.894' | 1,805 | 9.0 | 08/97 | present |
| Planting Cr. | 45° 48.972' | 121° 59.436' | 1,730 | 0.2 | 05/97 | present |
| Trout Cr.--above Hemlock | RNO ^b | | 1,120 | 3.4 | 11/98 ^d | present |
| Trout Cr.--below Hemlock | 45° 48.126' | 121° 55.810' | 1,080 | 2.9 | 10/98 | present |
| Martha Cr. | 45° 47.737' | 121° 55.342' | 1,080 | 1.0 | 10/97 | present |
| Panther Creek | | | | | | |
| Panther Cr.--upper | RNO | | 1,070 | 7.5 | 10/98 | present |
| Eightmile Cr.--upper | RNO | | 1,090 | 0.6 | 07/97 | present |
| Eightmile Cr.--lower | 45° 50.393' | 121° 52.069' | 1,030 | 0.2 | 07/97 | present |
| Cedar Cr. | 45° 48.176' | 121° 51.404' | 940 | 1.2 | 05/97 | present |
| Panther Cr.--lower 1 | RNO | | 730 | 4.0 | 07/97 | 09/97 |
| Panther Cr.--lower 2 | RNO | | 730 | 4.0 | 10/98 | present |

^a OG = Restored old-growth channel.

^b RNO = Reading not obtainable by GPS because of topography of basin.

^c No data from 4/22/98-10/19/98 because of thermograph failure.

^d Data for 11/96-5/97 are available from the US Forest Service.

Table 2. Flow measurement locations within the Wind River subbasin, 1996-98. Readings are from a hand-held Global Positioning System (GPS) using North American Datum 1927. Sites are listed from upstream to downstream within a subbasin.

| Watershed Subwatershed | GPS reading | | Elevation (ft) | Distance upstream of mouth (m) | Year sampled ^a | | |
|---------------------------|------------------|--------------|-------------------|--------------------------------------|---------------------------|------|------|
| | North | West | | | 1996 | 1997 | 1998 |
| Upper Wind River | | | | | | | |
| Paradise Cr. | 45° 56.951' | 121° 56.957' | 1,740 | 0.5 | No | No | Yes |
| Trapper Cr. | 45° 52.761' | 121° 58.849' | 1,150 | 0.5 | No | No | Yes |
| Trout Creek | | | | | | | |
| Trout Cr.--upper | 45° 50.794' | 122° 01.961' | 1,920 | 12.2 | Yes | Yes | Yes |
| Crater Cr. | 45° 50.779' | 122° 01.036' | 1,920 | 0.1 | Yes | Yes | Yes |
| Layout Cr.--upper | RNO ^b | | 1,940 | 2.5 | No | No | Yes |
| Planting Cr. | 45° 48.972' | 121° 59.436' | 1,730 | 0.1 | No | Yes | Yes |
| Martha Cr. | 45° 47.767' | 121° 55.255' | 1,070 | 1.0 | No | Yes | Yes |
| Panther Creek | | | | | | | |
| Panther Cr.--lower | RNO | | 1,010 | 4.0 | Yes | No | No |
| Eightmile Cr.--lower | RNO | | 1,020 | 0.1 | No | Yes | Yes |
| Mouse Cr. | RNO | | 1,080 | 0.1 | Yes | No | No |
| Cedar Cr. | 45° 48.176' | 121° 51.404' | 940 | 1.2 | Yes | Yes | No |

^a Flows generally taken at regular intervals of time from June through October.

^b RNO = Reading not obtainable by GPS because of topography of basin.

Table 3. Locations and timing of population surveys using the removal method with electrofishing within the Wind River subbasin. Readings are from a hand-held Global Positioning System (GPS) using North American Datum 1927. Sites are listed from upstream to downstream within a subbasin relative to the mainstem.

| Watershed Subwatershed Subdrainage | Start point distance from mouth (km) | Length of reach (km) | <u>GPS reading at start point</u> | | <u>GPS reading at end point</u> | | Year sampled ^a | | |
|------------------------------------------|--------------------------------------------|----------------------------|-----------------------------------|-------------|---------------------------------|-------------|---------------------------|------|------|
| | | | North | West | North | West | 1996 | 1997 | 1998 |
| Upper Wind | | | | | | | | | |
| Big Hollow Cr. ^b | 0 (at mouth) | 0.5 | RNO ^c | | 45 55.275' | 121 58.719' | No | No | Yes |
| Trout Creek | | | | | | | | | |
| Trout Cr.--upper | 0 (at mouth) | 0.5 | 45 50.759' | 122 01.960' | 45 50.979' | 122 01.943' | Yes | Yes | No |
| Crater Cr. ^b | 0 (at mouth) | 0.5 | 45 50.759' | 122 01.960' | 45 50.847' | 122 02.275' | Yes | Yes | Yes |
| Trout Cr.--mainstem a ^b | 11.7 | 0.1 | 45 50.589' | 122 01.909' | 45 50.646' | 122 01.943' | Yes | Yes | Yes |
| Compass Cr. ^b | 0 (at mouth) | 0.5 | 45 50.524' | 122 01.870' | 45 50.432' | 122 02.133' | Yes | No | No |
| East Fork Trout Cr. | 0 (at mouth) | 0.4 | 45 50.187' | 122 01.489' | 45 50.452' | 122 01.345' | Yes | No | No |
| Layout Cr. | 0 (at mouth) | 1.0 | 45 49.749' | 122 01.478' | 45 49.643' | 122 01.989' | Yes | No | No |
| Trout Cr.--mainstem b | 8.6 | 0.1 | 45 49.332' | 122 00.679' | 45 49.353' | 122 00.754' | Yes | No | Yes |
| Planting Cr. ^b | 0 (at mouth) | 0.5 | 45 49.018' | 121 59.400' | 45 48.814' | 121 59.584' | Yes | Yes | No |
| Martha Cr. ^b | 0.9 | 0.4 | 45 47.772 | 121 55.248 | 45 47.691' | 121 55.255' | No | Yes | Yes |
| Panther Creek | | | | | | | | | |
| Mouse Cr. ^b | 0 (at mouth) | 0.5 | 45 50.574' | 121 51.522' | 45 50.383' | 121 51.332' | Yes | No | No |
| Eightmile Cr.--upper | 0.7 | 0.5 | 45 50.529' | 121 52.367' | 45 50.597' | 121 52.710' | Yes | No | Yes |
| Eightmile Cr.--lower | 0 (at mouth) | 0.6 | 45 50.364' | 121 52.100' | 45 50.529' | 121 52.360' | Yes | Yes | Yes |
| Cedar Cr. | 1.0 | 0.6 | 45 48.097' | 121 51.512' | RNO | | Yes | No | No |

^a Electrofishing sampling conducted during August through mid-October. Results from 1996 and 1997 were reported in Connolly (1997) and in Connolly et al. (1997), respectively.

^b Locations sampled in 1984 by Crawford et al. (1985).

^c RNO = Reading not obtainable by GPS because of topography of basin.

Table 4. Assemblages of fish species observed in streams of the Wind River subbasin during electrofishing and snorkeling surveys, 1996-1998. Watersheds and streams are listed in an upstream to downstream pattern. P = present, A = absent.

| Watershed Stream | Steelhead trout^a | Shorthead sculpin | Brook trout^b | Chinook salmon^b |
|-----------------------------|----------------------------------------|------------------------------|------------------------------------|---------------------------------------|
| Upper Wind River | | | | |
| Paradise Creek | P | P | A | P |
| Big Hollow Creek | P | P | A | A |
| Ninemile Creek | P | P | A | A |
| Trapper Creek | P | P | A | P |
| Trout Creek | | | | |
| Trout Creek--upper | P | A | P | A |
| Crater Creek | P | A | P | A |
| Trout Creek—at Road 33 | P | A | P | A |
| Compass Creek | P | A | P | A |
| East Fork Trout Creek | P | A | P | A |
| Layout Creek | P | A | P | A |
| Trout Creek—at Road 43 | P | A | P | A |
| Planting Creek | P | A | A | A |
| Martha Creek | P | A | A | A |
| Panther Creek | | | | |
| Mouse Creek | P | P | A | A |
| Eightmile Creek--upper | P | P | A | A |
| Eightmile Creek--lower | P | P | A | A |
| Cedar Creek | P | P | A | A |

^a It was not determined what portion, if any, of these fish were resident rainbow trout, but anadromous steelhead had access to all stream sections sampled.

^b These species are considered nonnative to the Wind River subbasin above Shipherd Falls.

Table 5. Streams sampled for juvenile steelhead in the Wind River Basin during summer 1998. Watersheds and streams are listed in an upstream to downstream pattern.

| Watershed | |
|------------------------------|----------------------------------------------|
| Stream reach or section | Method and length surveyed |
| Upper Wind River | |
| Paradise Creek | Snorkel Survey, 16 of 35 pools within 1000 m |
| Big Hollow Creek (Dry Creek) | Electrofishing survey within 500 m |
| Trapper Creek | Snorkel Survey, 13 of 13 pools within 1000 m |
| Trout Creek | |
| Crater Creek | Electrofishing survey within 500 m |
| Mainstem reaches — A | Snorkeled 100 m, electrofished 100 m |
| — B | Snorkeled 100 m, electrofished 100 m |
| — C | Snorkeled 100 m |
| — D | Snorkeled 100 m |
| — E | Snorkeled 100 m |
| Martha Creek | Electrofishing survey within 500 m |
| Panther Creek | |
| Eightmile Creek—Upper | Electrofishing survey within 500 m |
| Eightmile Creek—Lower | Electrofishing survey within 500 m |

Table 6. Maximum temperature as recorded by thermographs located within the Wind River subbasin. Sites are listed from upstream to downstream within a subbasin. Information on location of thermographs is given in Table 3 of this report.

| Watershed Subwatershed Subdrainage | No. days >16°C | | No. days >18°C | | No. days >20°C | |
|------------------------------------------|------------------|------|----------------|------|----------------|------|
| | 1997 | 1998 | 1997 | 1998 | 1997 | 1998 |
| Trout Creek | | | | | | |
| Trout Cr.--upper | 0 | 0 | 0 | 0 | 0 | 0 |
| Crater Cr. | 23 | 44 | 1 | 17 | 0 | 1 |
| Trout Cr.--33 bridge | 0 | 0 | 0 | 0 | 0 | 0 |
| Compass Cr. | 0 | 5 | 0 | 0 | 0 | 0 |
| Trout Cr.--upper OG ^a | --- ^b | 0 | --- | 0 | --- | 0 |
| Layout Cr. | --- | 56 | --- | 24 | --- | 0 |
| Trout Cr.--43 bridge | 13 | 22 | 0 | 3 | 0 | 0 |
| Planting Cr. | 16 | 33 | 1 | 7 | 0 | 0 |
| Trout Cr.--above Hemlock | --- | 74 | --- | 46 | --- | 23 |
| Martha Cr. | --- | 62 | --- | 29 | --- | 5 |
| Panther Creek | | | | | | |
| Panther Cr.--upper | --- | --- | --- | --- | --- | --- |
| Eightmile Cr.--upper | 0 | 2 | 0 | 0 | 0 | 0 |
| Eightmile Cr.--lower | 29 | 39 | 4 | 6 | 0 | 0 |
| Cedar Cr. | 0 | 10 | 0 | 0 | 0 | 0 |
| Panther Cr.--lower 1 | 0 | 0 | 0 | 0 | 0 | 0 |

^a OG = Restored old-growth channel.

^b --- = Thermograph not in place or not operating.

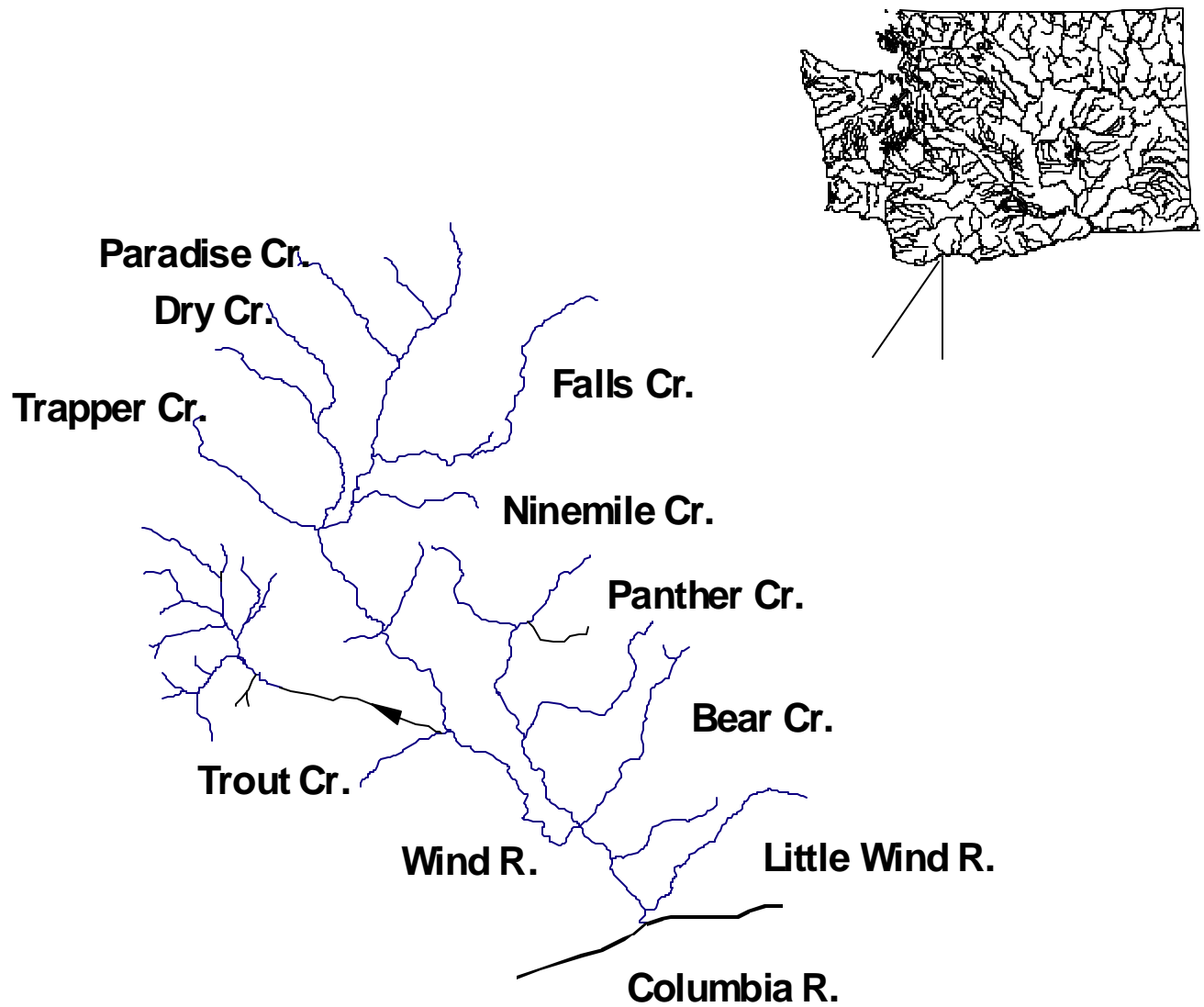


Figure 1. Wind River watershed.

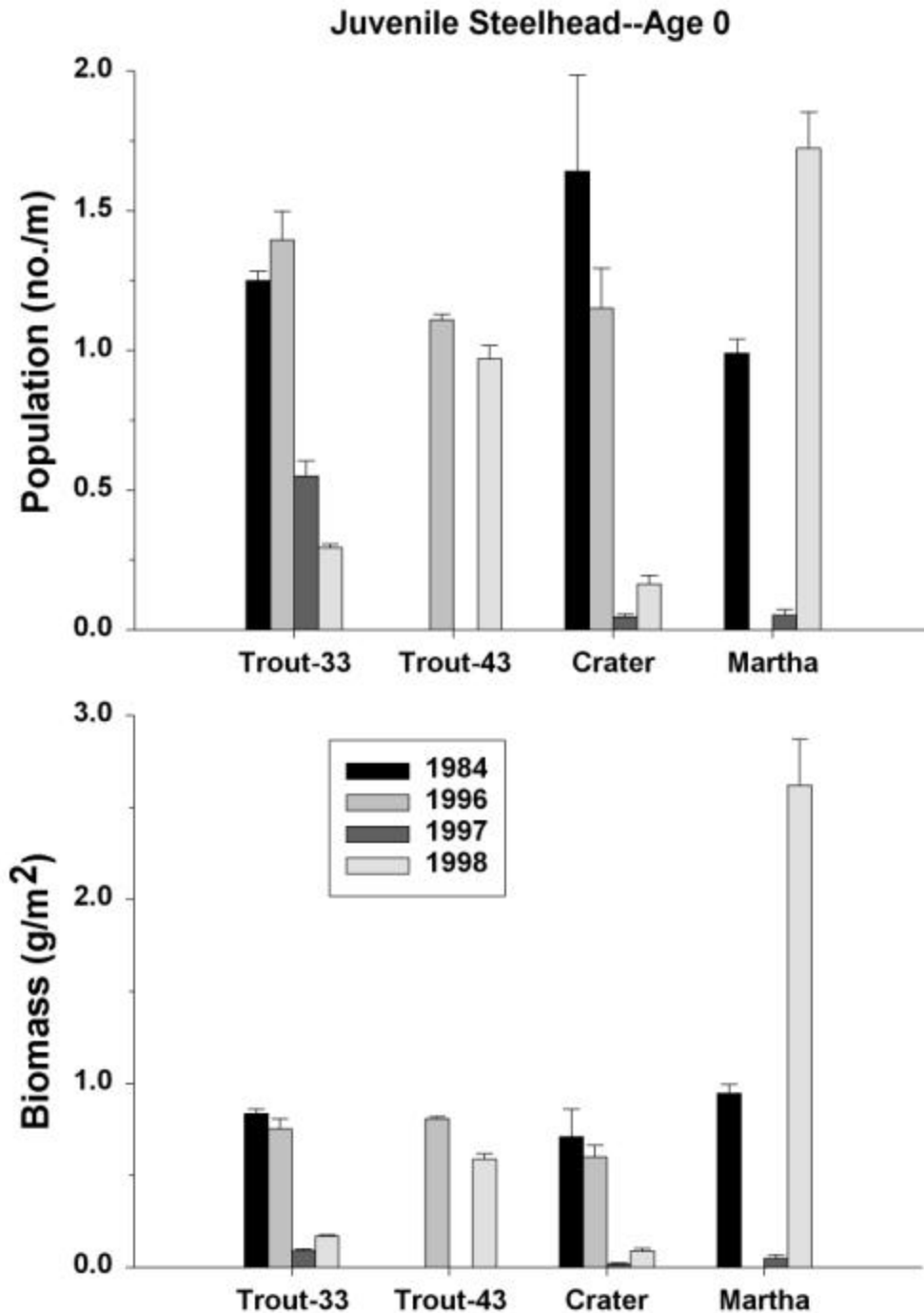


Figure 2. Comparison of age-0 steelhead population and biomass estimates from Trout Creek for 1984, 1996-1998. Vertical lines above bars represent one standard error. The 1984 data are from Crawford et al. (1985) as revised by Connolly (1997), the 1996 data are from Connolly (1997), the 1997 data are from Connolly et al. (1997), and the 1998 data are from the present BPA-funded study. Where no histogram bar is drawn, the stream was not sampled during that year.

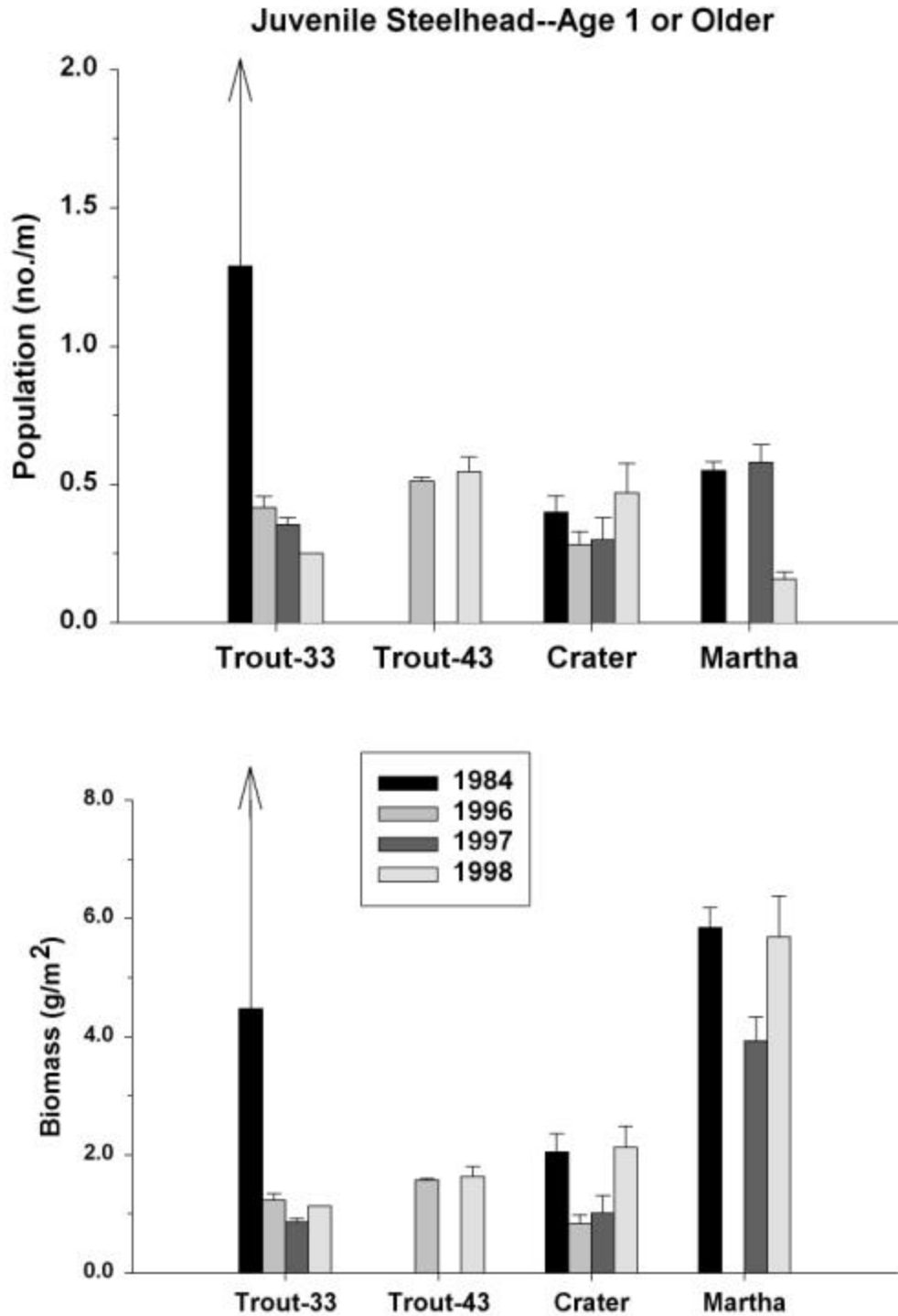


Figure 3. Comparison of age-1 or older steelhead population and biomass estimates from Trout Creek for 1984, 1996-1998. Vertical lines above bars represent one standard error. The arrow above the 1984 bars indicate a very large standard error (CV=354%). The 1984 data are from Crawford et al. (1985) as revised by Connolly (1997), the 1996 data are from Connolly (1997), the 1997 data are from Connolly et al. (1997), and the 1998 data are from the present BPA-funded study. Where no histogram bar is drawn, the stream was not sampled during that year.

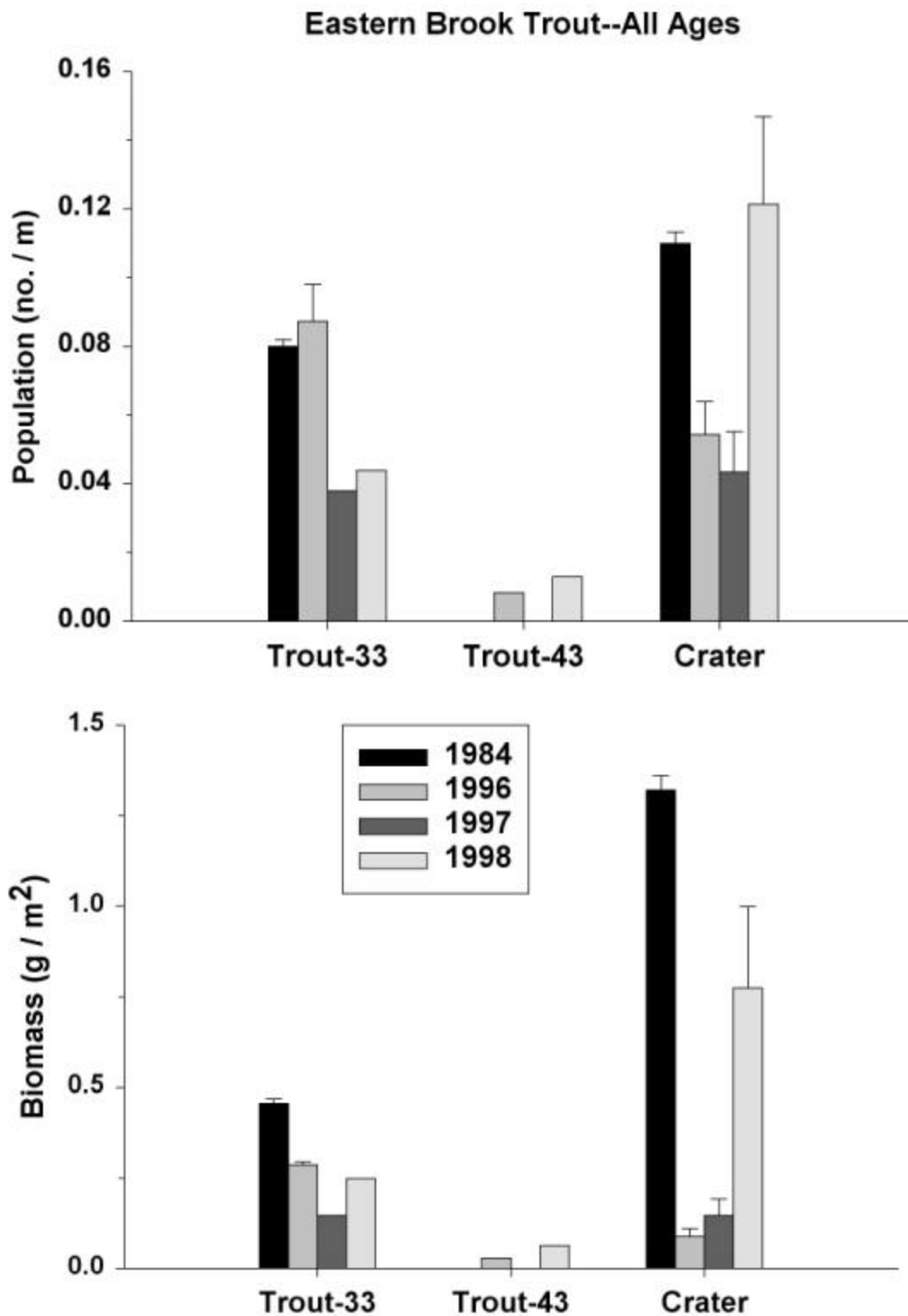


Figure 4. Comparison of eastern brook trout population and biomass estimates from Trout Creek for 1984, 1996-1998. Vertical lines above bars represent one standard error. The 1984 data are from Crawford et al. (1985) as revised by Connolly (1997), the 1996 data are from Connolly (1997), the 1997 data are from Connolly et al. (1997), and the 1998 data are from the present BPA-funded study. Trout-43 was not sampled in 1984 or 1987.

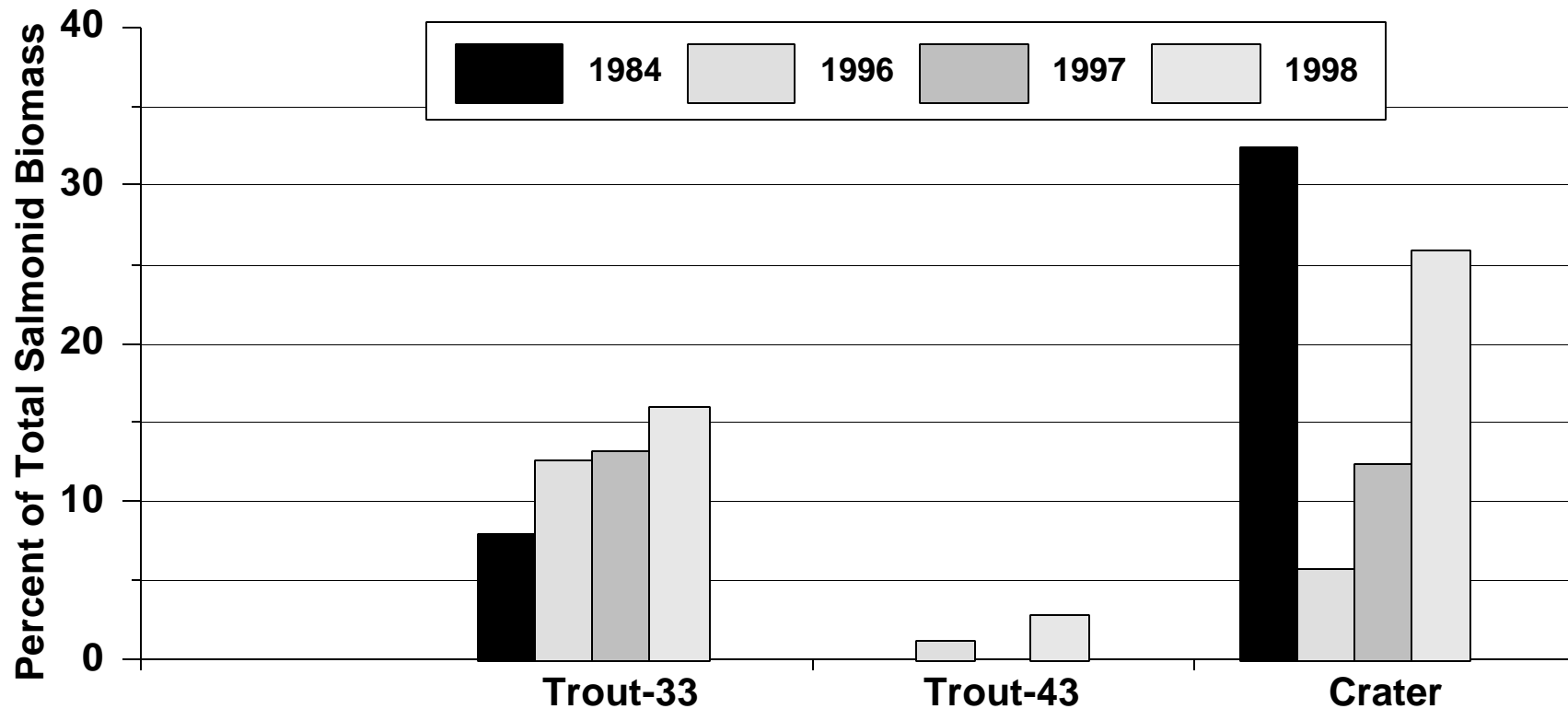


Figure 5. Contribution of eastern brook trout to the total salmonid biomass estimates from Trout Creek for 1984, 1996-1998. The 1984 data are from Crawford et al. (1985) as revised by Connolly (1997), the 1996 data are from Connolly (1997), the 1997 data are from Connolly et al. (1997), and the 1998 data are from the present BPA-funded study. Trout-43 was not sampled in 1984 or 1997.

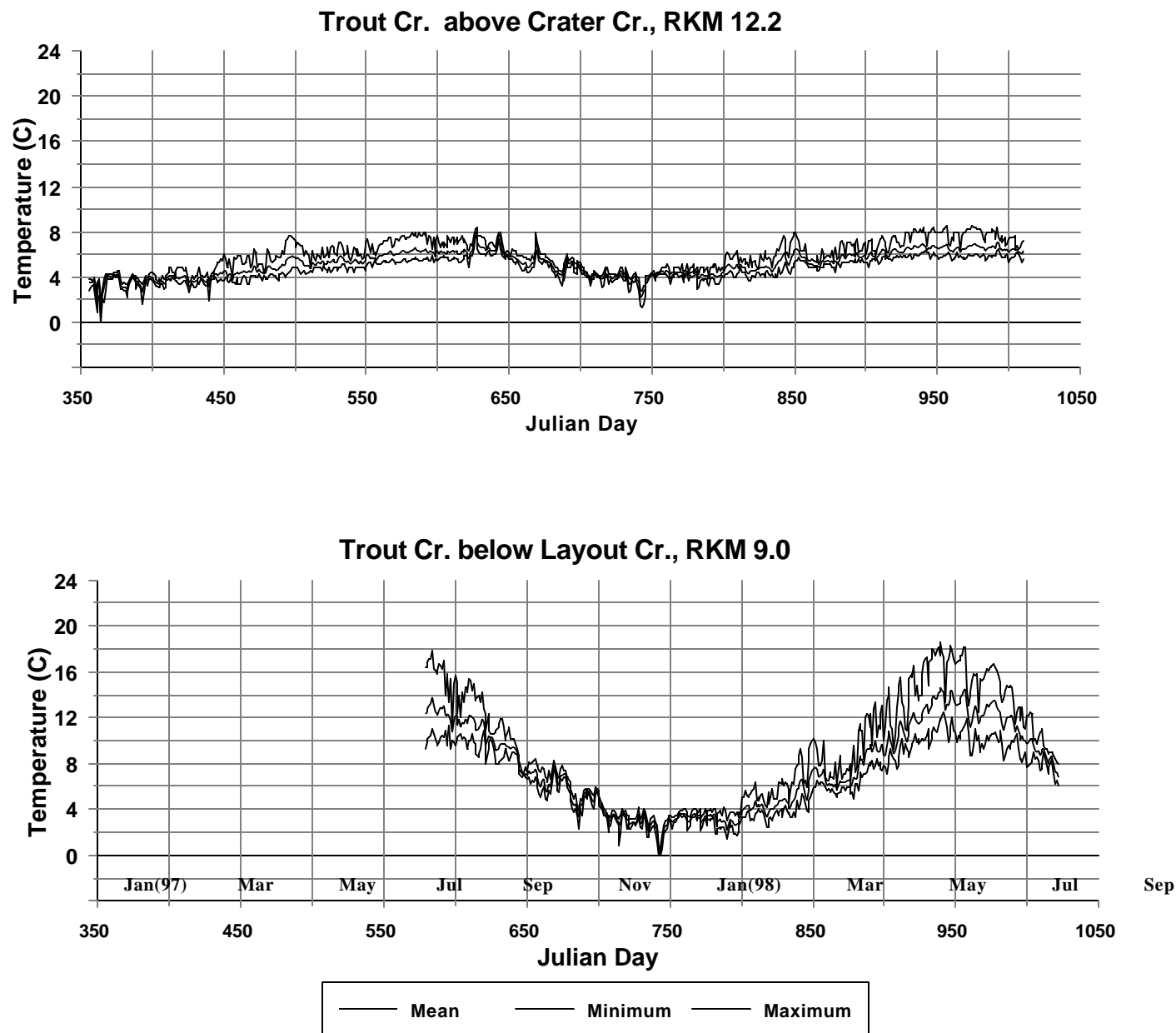


Figure 6. Daily minimum, mean, and maximum water temperatures at two sites in the mainstem Trout Creek. RKM = river kilometers, the number of kilometers above mouth of Trout Creek.

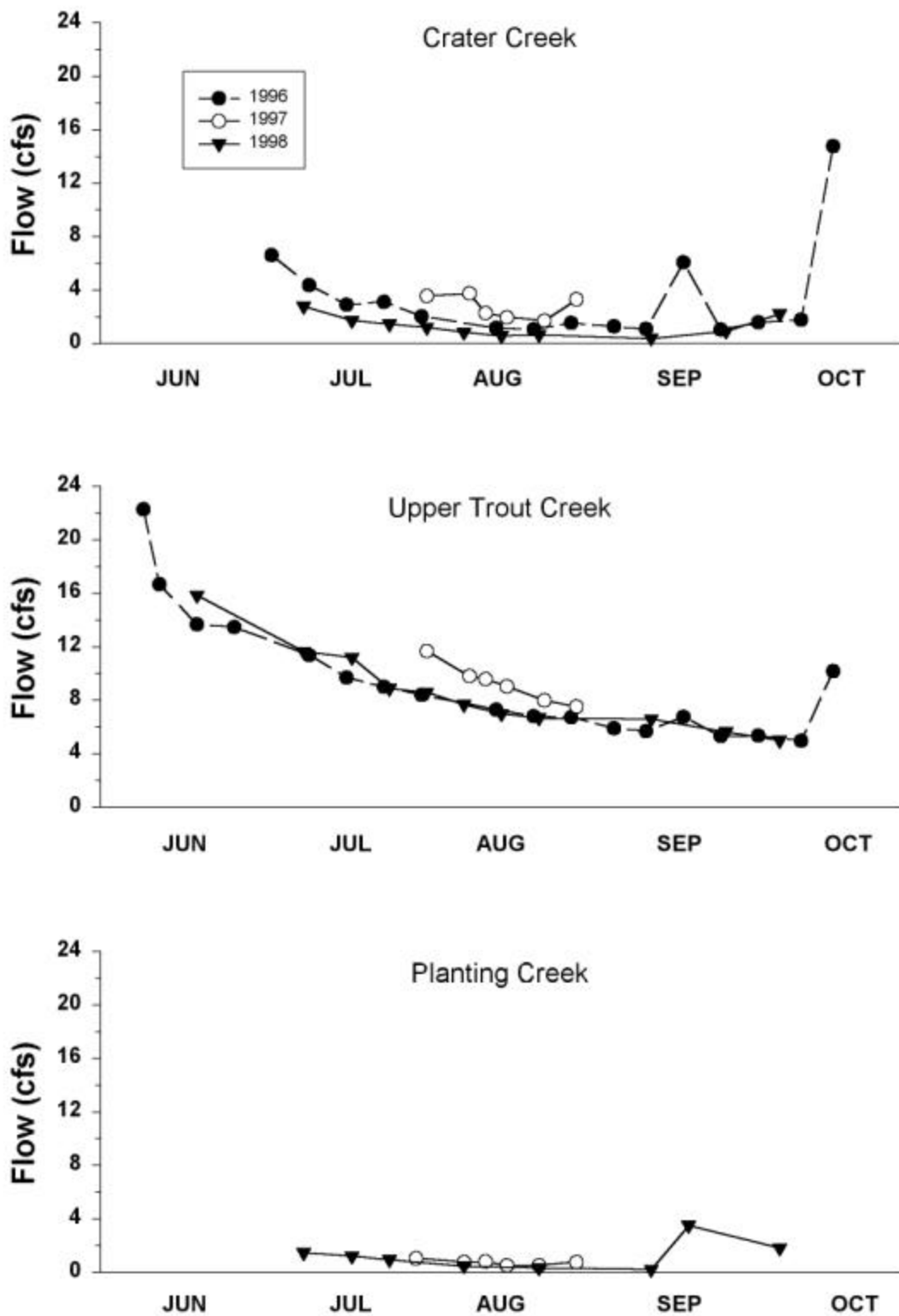


Figure 7. Water flow levels for Crater, upper Trout, and Planting creeks in the Trout Creek watershed, 1996-1998. For locations of measurement sites, see Table 2 of this report.

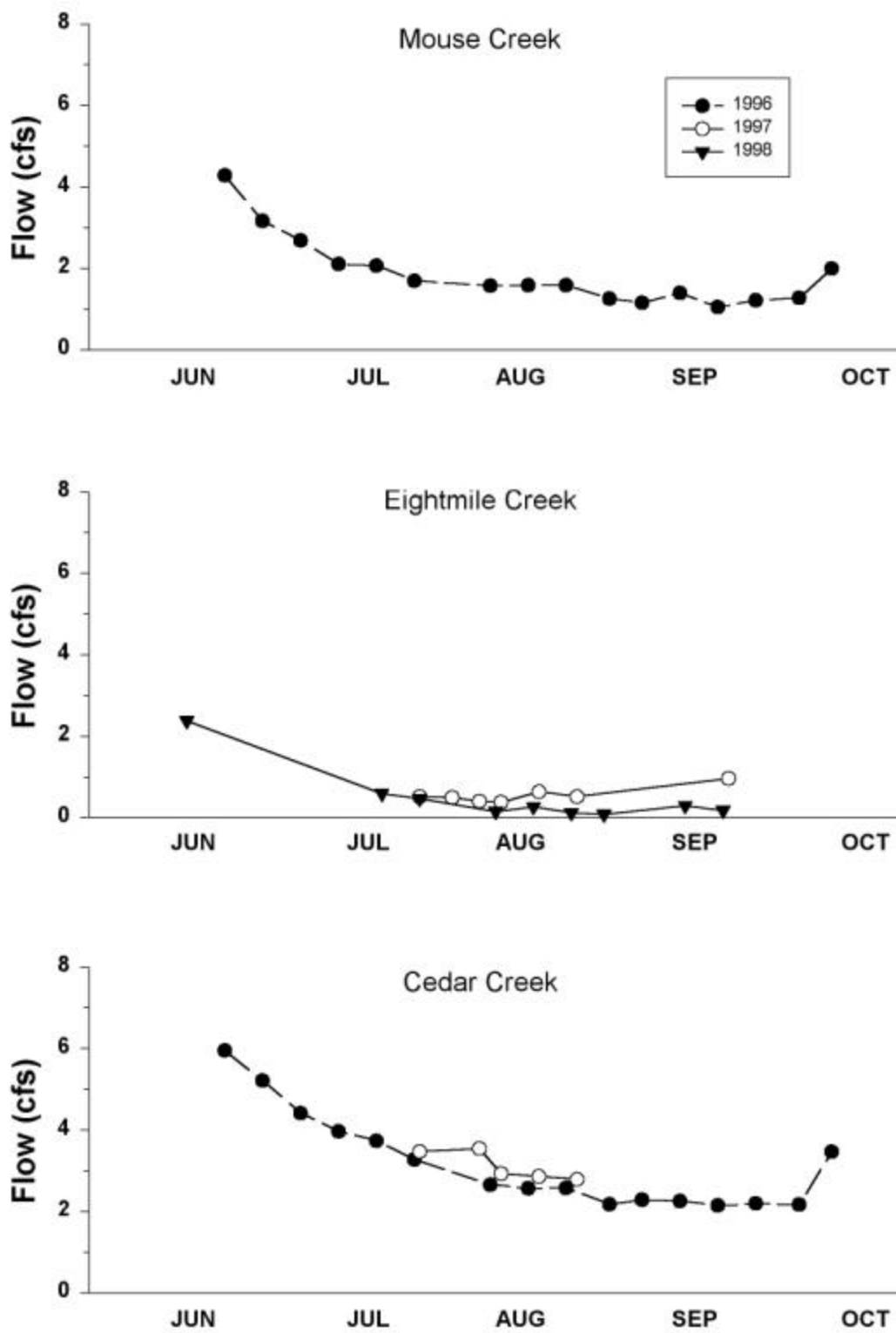


Figure 8. Water flow levels for Mouse, Eightmile, and Cedar creeks in the Panther Creek watershed, 1996-1998. For locations of measurement sites, see Table 2 of this report.